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GEODESY.—*The distance between two widely separated points on the surface of the earth.*[1] WALTER D. LAMBERT, U. S. Coast and Geodetic Survey.

Suppose two points on the earth to be given by their latitudes and longitudes: What is the length of the line joining the points and what is its direction at these end points? The problem will be discussed and the results stated and illustrated, the proofs being deferred to another occasion.

If we treat the earth as a sphere of given radius, the "line" joining the two points is the arc of a great circle less than 180°, which gives the shortest distance between them, and the problem is one of spherical trigonometry. Two sides and the included angle of a spherical triangle are, in effect, given.

A second approximation to the figure of the earth is a slightly flattened ellipsoid of revolution. It is of interest to inquire what the effect of the flattening is on the length and the direction of the "line" joining the two points. In what follows it will be assumed without much discussion that the line connecting the two points is a geodesic line, or simply a *geodesic*. The geodesic on an ellipsoid of revolution corresponds to an arc of great circle on a sphere or to a straight line in a plane. If we let the flattening of the ellipsoid decrease to zero, a geodesic on the ellipsoid becomes an arc of great circle on the limiting sphere; but, unlike the arc of a great circle, an indefinitely extended geodesic on an ellipsoid does not generally return into itself. Even if we reject those geodesics roughly analogous to arcs of a great circle greater than 2π, we find that there may be more than one geodesic between the same two points. Although the shortest distance is always measured along a geodesic, not every geodesic gives a shortest distance.

[1] Received February 24, 1942.

When two points A and B are intervisible the lines actually observed by a surveyor are the two plane sections of the surface: (1) by a plane containing the normal at A and the point B; (2) by a plane containing the normal at B and the point A. These plane sections are in general two distinct curves and a plane section has its characteristic property for only one of its points, the point where the plane contains the normal to the surface; in this it differs from the geodesic on the ellipsoid, from the arc of great circle on the sphere, and from the straight line in the plane. All these have their characteristic properties for all their points, with the possible limitation that the points must not be too far apart. Later an illustration will be given that will show the inapplicability of the idea of a plane section to the present problem.

In deriving the formulas to be given it is necessary to use the parametric, or reduced, latitude of a point on an ellipsoid of revolution, even though the reduced latitude does not appear explicitly in one group of formulas hereinafter given.

Let a and b be the semimajor and semiminor axes of an oblate ellipsoid of revolution. Let f denote flattening, $(a-b)/a$. Let ϕ denote the geographic latitude of a point (inclination of the normal to the surface at the point to the plane of the equator) and β the corresponding reduced or parametric latitude. The relation between ϕ and β is

$$\tan \beta = \frac{b}{a} \tan \phi = (1-f) \tan \phi. \quad (1)$$

Approximately, by neglecting small quantities of the order f^2, we have in radians

$$\phi-\beta=\tfrac{1}{2}f \sin 2\phi=\tfrac{1}{2}f \sin 2\beta.$$

Astronomers sometimes use the geocentric latitude ψ, connected with the geographic latitude ϕ by the relation

$$\tan \psi=\frac{b^2}{a^2}\tan \phi,$$

or approximately in radians

$$\phi-\psi=f \sin 2\phi.$$

If we have tables of $\phi-\psi$, the reduction from geographic to geocentric latitude, we may take half this reduction as the approximate reduction from geographic to parametric latitude.

First assume that the parametric latitudes of the points A and B have been found and are β_1 and β_2, respectively, and that the difference of longitude is $\lambda(\lambda<180°)$. On a sphere λ is the angle at the north pole, C, between the two sides of a spherical triangle; the lengths of these sides, AC and BC, are $90°-\beta_1$ and $90°-\beta_2$ (south latitudes are treated as negative). We may solve this triangle by any of various formulas for the side AB opposite C, which call σ, and for the angles at A and B, which we may denote by the same letters A and B, as is usual in trigonometric formulas. These angles give the directions at A and B of the arc AB.

In surveying it is usual to specify direction by azimuth, reckoned from south by way of west around to 360°. If B is west of A and west longitudes are reckoned as positive, it is easy to see by drawing a figure that the azimuths α_1 and α_2 at A and B are connected with the angles A and B of the triangle by the relations

α_1 = forward azimuth of AB at $A=180°-A$

α_2 = back azimuth at $B=180°+B$

(in direction BA)

The following formulas for the solution of the triangle ACB come from Delambre's (Gauss's) equations for a spherical triangle. The results are expressed directly in terms of the azimuth instead of in terms of the angles of the triangle.

Let $\beta=\frac{1}{2}(\beta_2+\beta_1)$, $\Delta\beta=\frac{1}{2}(\beta_2-\beta_1)$

$$\left.\begin{aligned}
\sin \tfrac{1}{2}(\alpha_2+\alpha_1) \sin \tfrac{1}{2}\sigma &= -\sin \Delta\beta \cos \tfrac{1}{2}\lambda \\
\cos \tfrac{1}{2}(\alpha_2+\alpha_1) \sin \tfrac{1}{2}\sigma &= -\cos \beta \sin \tfrac{1}{2}\lambda \\
\sin \tfrac{1}{2}(\alpha_2-\alpha_1) \cos \tfrac{1}{2}\sigma &= \cos \Delta\beta \cos \tfrac{1}{2}\lambda \\
\cos \tfrac{1}{2}(\alpha_2-\alpha_1) \cos \tfrac{1}{2}\sigma &= \sin \beta \sin \tfrac{1}{2}\lambda
\end{aligned}\right\} \quad (2)$$

These formulas are proposed rather than other possible ones because: (1) they are nearly self-checking in ways that the experienced computer will readily observe; (2) they are adapted to obtaining the greatest possible accuracy from trigonometric tables to a given number of places; (3) the quantities used are needed later in reducing from the sphere to the ellipsoid.

Though they are nearly self-checking, there is still a possibility that certain errors may escape detection that would be detected by the law of sines, namely,

$$\frac{\sin \lambda}{\sin \sigma}=\frac{\sin \alpha_1}{\cos \beta_2}=-\frac{\sin \alpha_2}{\cos \beta_1}.$$

The azimuths α_1 and α_2, since they have been obtained from the sphere, need corrections to reduce them to their values on the ellipsoid. If we assume the radius of the sphere to be a, the semimajor axis of the ellipsoid, the distance on the sphere $= AB=s=a\sigma$ (σ in radians) also needs correction to reduce to the distance along a geodesic on the ellipsoid. The required corrections $\delta\alpha_1$, $\delta\alpha_2$, and δs are

$$\begin{aligned}
\delta\alpha_1 &= (f \cos^2 \beta_2 \sin \alpha_2 \cos \alpha_2)\frac{\sigma}{\sin \sigma} \\
&= N\sigma/\sin \sigma
\end{aligned} \quad (3)$$

$$\begin{aligned}
\delta\alpha_2 &= (f \cos^2 \beta_1 \sin \alpha_1 \cos \alpha_1)\frac{\sigma}{\sin \sigma} \\
&= M\sigma/\sin \sigma
\end{aligned} \quad (4)$$

where the meanings of M and N are obvious. $\delta\alpha_1$ and $\delta\alpha_2$ will be expressed in the same unit as σ.

$$\begin{aligned}
\delta s = &-\tfrac{1}{2}af(\sigma-\sin \sigma)\frac{\sin^2 \beta \cos^2 \Delta\beta}{\cos^2 \tfrac{1}{2}\sigma} \\
&-\tfrac{1}{2}af(\sigma+\sin \sigma)\frac{\cos^2 \beta \sin^2 \Delta\beta}{\sin^2 \tfrac{1}{2}\sigma}.
\end{aligned} \quad (5)$$

In (5) the σ within the parentheses must evidently be expressed in radians. We then have

$$\left.\begin{array}{c}\text{Forward azimuth on ellipsoid at } A \\ = \alpha_1 + \delta\alpha_1 \\ \text{Back azimuth on ellipsoid at } B \\ = \alpha_2 + \delta\alpha_2 \\ \text{Distance } AB \text{ on ellipsoid along} \\ \text{geodesic} = a\sigma + \delta s\end{array}\right\} \quad (6)$$

where α_1, α_2 and σ come from (2) and $\delta\alpha_1$, $\delta\alpha_2$ and δs from (3), (4), and (5).

A variant form for δs is

$$\delta s = -\tfrac{1}{2}af(\sigma - \sin\sigma)\cos^2\tfrac{1}{2}\sigma\,\frac{\sin^2(\alpha_2-\alpha_1)}{\sin^2\lambda} - \tfrac{1}{2}af(\sigma+\sin\sigma)\sin^2\tfrac{1}{2}\sigma\,\frac{\sin^2(\alpha_2+\alpha_1)}{\sin^2\lambda} \quad (7)$$

It is not necessary to compute the parametric latitudes if they are not known or readily available, but the resulting formulas when geographic latitudes are used are slightly more complex.

Compute the spherical triangle given, as before, by the included angle C at the north pole equal to λ, the difference in longitude of A and B, and by the including sides AC and BC, which are now equal to $90°-\phi_1$ and $90°-\phi_2$, where ϕ_1 and ϕ_2 are the geographic latitudes of A and B respectively.

By analogy with (2) we put

$$\phi = \tfrac{1}{2}(\phi_2+\phi_1) \qquad \Delta\phi = \tfrac{1}{2}(\phi_2-\phi_1)$$

$$\left.\begin{array}{l}\sin\tfrac{1}{2}\sigma\sin\tfrac{1}{2}(\alpha_2+\alpha_1) = -\sin\Delta\phi\cos\tfrac{1}{2}\lambda \\ \sin\tfrac{1}{2}\sigma\cos\tfrac{1}{2}(\alpha_2+\alpha_1) = -\cos\phi\sin\tfrac{1}{2}\lambda \\ \cos\tfrac{1}{2}\sigma\sin\tfrac{1}{2}(\alpha_2-\alpha_1) = \cos\Delta\phi\cos\tfrac{1}{2}\lambda \\ \cos\tfrac{1}{2}\sigma\cos\tfrac{1}{2}(\alpha_2-\alpha_1) = \sin\phi\sin\tfrac{1}{2}\lambda\end{array}\right\} \quad (8)$$

For a check the law of sines is

$$\frac{\sin\lambda}{\sin\sigma} = \frac{\sin\alpha_1}{\cos\phi_2} = -\frac{\sin\alpha_2}{\cos\phi_1}.$$

The values of α_1, α_2 and σ are not quite the same as those previously found; the differences are small quantities of the order f.

The corrections to be applied are

$$\delta\alpha_1 = (f\cos^2\phi_2\sin\alpha_2\cos\alpha_2)\sigma/\sin\sigma + f\cos^2\phi_1\sin\alpha_1\cos\alpha_1 \quad (9)$$
$$= N\sigma/\sin\sigma + M$$

$$\delta\alpha_2 = (f\cos^2\phi_1\sin\alpha_1\cos\alpha_1)\sigma/\sin\sigma + f\cos^2\phi_2\sin\alpha_2\cos\alpha_2 \quad (10)$$
$$= M\sigma/\sin\sigma + N.$$

If σ is in radians, formulas (9) and (10) as they stand give $\delta\alpha_1$ and $\delta\alpha_2$ in radians. We have used the same symbol, M, for $f\cos^2\beta_1\sin\alpha_1\cos\alpha_1$ and $f\cos^2\phi_1\sin\alpha_1\cos\alpha_1$ since these two quantities differ from one another by small quantities of the order f^2, quantities neglected in this discussion. Similarly for N.

For the distance we have now

$$\delta s = \tfrac{1}{2}af(3\sin\sigma-\sigma)\,\frac{\sin^2\phi\cos^2\Delta\phi}{\cos^2\tfrac{1}{2}\sigma} - \tfrac{1}{2}af(3\sin\sigma+\sigma)\,\frac{\cos^2\phi\sin^2\Delta\phi}{\sin^2\tfrac{1}{2}\sigma}. \quad (11)$$

As before, σ within the parentheses is expressed in radians. We then have

$$\left.\begin{array}{c}\text{Forward azimuth on ellipsoid at } A \\ = \alpha_1 + \delta\alpha_1 \\ \text{Back azimuth on ellipsoid at } B \\ = \alpha_2 + \delta\alpha_2 \\ \text{Distance } AB \text{ on ellipsoid along} \\ \text{geodesic} = a\sigma + \delta s\end{array}\right\} \quad (12)$$

where α_1, α_2 and σ come from (8) and the corrections to them from (9), (10), and (11). The quantities α_1, α_2, σ, $\delta\alpha_1$, $\delta\alpha_2$, and δs differ from the like-named quantities obtained from (2), (3), (4), and (5) by small quantities of the order f^2, but the combinations $\alpha_1+\delta\alpha_1, \alpha_2+\delta\alpha_2$ and $a\sigma+\delta s$ are nearly the same in (6) and (12). See the numerical examples.

Alternative formulas are

$$\delta s = \tfrac{1}{2}af(3\sin\sigma-\sigma)\,\frac{\cos^2\tfrac{1}{2}\sigma}{\sin^2\lambda}\sin^2(\alpha_2-\alpha_1) - \tfrac{1}{2}af(3\sin\sigma+\sigma)\,\frac{\sin^2\tfrac{1}{2}\sigma}{\sin^2\lambda}\sin^2(\alpha_2+\alpha_1) \quad (13)$$

$$\left.\begin{aligned} \tfrac{1}{2}(\delta\alpha_2+\delta\alpha_1) &= -\tfrac{1}{2}f\left(\frac{\sigma}{\sin\sigma}+1\right) \\ &\quad \cdot\cos\phi_1\cos\phi_2\sin(\alpha_2+\alpha_1) \\ \tfrac{1}{2}(\delta\alpha_2-\delta\alpha_1) &= -\tfrac{1}{2}f\left(\frac{\sigma}{\sin\sigma}-1\right) \\ &\quad \cdot\cos\phi_1\cos\phi_2\sin(\alpha_2-\alpha_1) \end{aligned}\right\} \quad (14)$$

$\delta\alpha_2$ and $\delta\alpha_1$ are obtained from (14) by addition and subtraction.

The formulas for $\delta\alpha_1$ and $\delta\alpha_2$ contain the factor $\sigma/\sin\sigma$. When σ is small this factor is nearly unity and no difficulty arises, but when σ is nearly 180°, that is, when the points A and B are nearly antipodal, $\sigma/\sin\sigma$ is large. A necessary condition that the preceding formulas give at least a first rough approximation to the effect of the flattening on the azimuths is that $\pi-\sigma>f\pi$; or $180°-\sigma>f$ 180°, if σ be in sexagesimal measure. For the earth f 180° is about 36 minutes of arc. In practice $180°-\sigma$ should amount to several degrees. The behavior of geodesic lines between two nearly antipodal points is rather curious but the exposition would require considerable space.

Some idea of the possible complications encountered in seeking the line of minimum length between nearly antipodal points may be obtained by considering points on the Equator. Between two points on the Equator not too far apart the Equator itself is obviously a geodesic and a line of minimum length.

But let the two points on the Equator be exactly 180° apart in longitude. The shortest distance between them is along the meridian over the pole. This route takes advantage of the flattening of the earth to decrease the distance traveled. Suppose the difference in longitude to be, not $180°=\pi$ radians, but $\pi\ (1-\epsilon)$ radians. It can be shown that for ϵ sufficiently small there is a route between the two points that takes advantage of the flattening by leaving the Equator and going north or south but not all the way to a pole. The azimuth, α, of the geodesic of minimum length and the highest parametric latitude, β_0, attained by it are given approximately by

$$\sin\alpha=\cos\beta_0=\epsilon/f,$$

where f is, as usual, the flattening.

Let us take the flattening as 1/300 in round numbers (the value adopted internationally is 1/297); we have the following table of approximate values:

TABLE 1.—PROPERTIES OF A MINIMUM GEODESIC BETWEEN TWO POINTS ON EARTH'S EQUATOR
($f=1/300$ $a\pi=20{,}000$ km)

Diff. long. λ	Az. of geodesic α	Max. lat. β_0	Dist. saved s_E-s_G
179°24′	90°	0°	0
179 30	123.6	33.6	$\frac{1}{75}af\pi=$ 0.9 km
179 36	138.2	48.2	$\frac{1}{75}af\pi=$ 3.7
179 42	150.0	60.0	$\frac{1}{75}af\pi=$ 8.3
179 48	160.5	70.5	$\frac{11}{75}af\pi=14.7$
179 54	170.4	80.4	$\frac{11}{75}af\pi=23.1$
180 00	180	90	$\frac{11}{75}af\pi=33.3$

s_E is the length along the Equator, s_G the length along the geodesic. There are obviously two symmetrical geodesics, one in each hemisphere. The figures in the table apply to the geodesic in the northern hemisphere. For difference of longitude equal to 180° the meridian and the Equator are both vertical sections; for any pair of points on the equator, the equator itself is *the* vertical section but does not necessarily give the minimum distance.

No attempt has been made to evaluate the omitted terms in f^2, f^3, etc. Presumably the coefficients would be extremely complicated. Some idea of the accuracy obtainable with the formulas here given may be obtained from the numerical examples in Table 2.

The table gives: (1) the results, marked a, from formulas (2), (3), (4), (5), and (6), using reduced latitudes; (2) the results, marked b, from formulas (8), (9), (10), (11), and (12), using geographic latitudes; and (3) the results from a more accurate process, marked c, using the necessary number of successive approximations to obtain all the accuracy possible with a seven-place table.

It must be remembered that seven-place tables leave the final figures of the results given decidedly uncertain, so that the discrepancies between results a and b and between either and the accurate result c is

not necessarily much greater than that due to omitted decimals. We may fairly say that for examples I-IV inclusive the theoretical accuracy of the approximate formulas and the numerical accuracy obtainable with six-place tables are about the same.

But in example V, the errors due to omitted terms are much greater. Here the points are within 6° of being antipodal. This 6° is ten times the limit f 180° previously given. For points more nearly antipodal than in V the approximation may be expected to be still rougher. The distance in example V by the approximate formulas is fairly accurate; this is to be expected.

Several years before the publication of Andoyer's article the writer of this note had the proofs for formulas equivalent to all those given above but did not publish them.

The process given in this note is only a first approximation and fails for nearly antipodal points. The rigorous solution in any case requires successive approximations and the inclusion of terms of higher order than the first-order terms here considered. The method is explained briefly in Clarke's *Geodesy* (Oxford, 1880), chapter 6, and much more fully with abundant numerical illustrations in Helmert's *Die mathematischen und physikalischen Theorieen der höheren Geodäsie* 1, chapters 5 and 7 (Leipzig, 1880).

The behavior of a system of geodesics issuing in all directions from a fixed point and extending about halfway around the ellipsoid is treated by Clarke and more fully by Helmert. There is also a posthumous note by Jacobi completed by A. Wangerin in vol. 7 (p. 72) of his Jacobi's *Gesammelte Werke*, entitled "Über die Curve, welche alle von einem Punkte angehenden geodätischen Linien eines Rotationsellipsoid berührt."

A very full treatment of the same general subject was published by E. Fichot in the Annales Hydrographiques (ser. 3) 4: 99, 1921,

TABLE 2.—COMPARISON OF THE VARIOUS FORMULAS

Spheroid	I Clarke, 1866	II Bessel	III Bessel	IV Clarke, 1866	V Clarke, 1866
a (km)	6378.206	6377.397			
$1/f$	294.98	299.15			
ϕ^1	+25°00′	+51°12′	+55°45′	+26°29′06″.57:	−55°00′
ϕ_2	+65 00	+51 55	−33 28	+55 00	+65 00
λ	+50 00	+69 03	−108 13	+30°07′38″.94	+174 00
$\alpha_1+\delta\alpha_1$	135°18′	119°09′	222°07′	150°32′	214°
(a)	25″.40	18″.24	38″.82	53″.12	34′52″.49
(b)	26 .39	18 .18	38 .02	53 .37	35 01 .85
(c)	25 .45	18 .20	38 .00	53 .10	35 31 .15
$\alpha_2+\delta\alpha_2$	296°37′	242°30′	83°23′	310°00′	150°
(a)	45″.48	57″.30	50″.09	00″.16	20′08″.53
(b)	46 .49	57 .39	49 .53	00 .21	20 00 .32
(c)	45 .45	57 .32	51 .18	00 .00	19 40 .51
$s+\delta s$ (km)	5675	4602	14110		19344
(a)	.585	.925	.52	3999.997	.27
(b)	.605	.910	.48	4000.011	.29
(c)	.591	.920	.53	4000.000	.22

BIBLIOGRAPHICAL NOTE

Formula (11), the correction to the distance computed on a sphere with geographic latitudes, has for some years past been given without proof in the *Annuaire du Bureau des Longitudes*. It is presumably due to Henri Andoyer. A proof by him dated 1927 was published posthumously in the Bulletin géodésique (No. 34, p. 77, 1932) under the title "Formule donnant la longueur de la géodésique joignant 2 points de l'ellipsoïde donnés par leurs coordonnées géographiques."

under the title "Sur les systèmes géodésiques equilatères à la surface du sphéroïde terrestre." The subject is continued by E. Fichot and P. Gerson in the Annales (ser. 3) **5**: 1937, under the title: "La zone géodésique antipode."

There is an article by Cayley in the London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science **40**: 329, 1870, entitled: "On the Geodesic Lines on an Oblate Spheroid," in which the results are expressed in terms of elliptic integrals.

There appears to be no comprehensive treatment readily available in English. The author hopes to publish one shortly.

For reduced, geocentric, and other kinds of latitude and their relation to geographic latitude see O. S. Adams, *Latitude developments connected with geodesy and cartography*, U. S. Coast and Geodetic Survey Special Publication No. 67.

CHEMISTRY.—*The determination of the cystine content of various proteins by different hydrolytic agents, sulphuric, hydrochloric, hydriodic, and a mixture of hydrochloric and formic acids.*[1] W. C. Hess and M. X. Sullivan, Georgetown University.

In the analysis of proteins some type of hydrolysis must be employed to separate the complex material into the constituent amino acids. Occasionally, as for example in the estimation of tryptophane, a mild alkaline hydrolysis with $Ba(OH)_2$ has been found useful, but for most of the amino acids an acid hydrolysis is necessary. For years workers in the protein field have hydrolyzed with 20 per cent HCl or with 6N H_2SO_4 or, occasionally, with stronger H_2SO_4. Many proteins however, on hydrolysis with these acids form black soluble or insoluble humin. Because of the necessity of decolorizing the black solution and the possible loss of reactive amino acid in the formation of the humin, soluble or insoluble, various investigators have sought to hydrolyze under conditions that avoid humin formation as much as possible.

Sullivan (1) early recommended hydrolyzing with HCl containing $TiCl_3$, and Sullivan and Hess (2) found not only that in such an hydrolysis there was an inhibition of humin formation but also that the time required for hydrolysis was greatly lessened. Then Baernstein (3) emphasized the fact that no humin is formed if proteins are hydrolyzed by HI containing H_3PO_2, and Miller and du Vigneaud (4) reported that a mixture of HCl and HCOOH was superior to HCl for the estimation of cystine in insulin.

[1] Received February 9, 1942.

If the protein is properly hydrolyzed there are several methods of estimating the cystine, and of these the Sullivan method (1) is the most specific and accurate. If the hydrolysis is conducted in a reducing atmosphere as with HI and H_3PO_2 the solution contains not cystine but the reduced form cysteine. In general, sulphuric acid has been found to be a less efficient hydrolytic agent than HCl in that it requires a longer period of heating (5). In work with edestin Kassell and Brand (6), however, report that hydrolysis with H_2SO_4 gives low results for cystine particularly with the Sullivan method, whether the time of hydrolysis is 8 or 15 hours, a finding they attribute to the tendency of the H_2SO_4 to produce substances that interfere with the Sullivan reaction, a situation they find also with HCl if the time of hydrolysis is long. Provided the acids are free from impurities we have never met with such interference. Higher values after precipitation with cuprous chloride, as found by Kassell and Brand, do not necessarily indicate the presence of inhibiting material since cuprous chloride opens a number of cystine complexes that do not react of themselves in the Sullivan reaction (7).

In fact, in work on the determination of cystine in zein we obtained practically the same value whether the hydrolytic agent was H_2SO_4 or HCl, and so were at a loss to account for the findings of Kassell and

Brand with edestin. Accordingly we submitted 10 proteins at our disposal to digestion with H_2SO_4, HCl, HCl-HCOOH, and HI for periods of time considered optimum for the respective acid and estimated the cystine in the hydrolysates by means of the Sullivan method and the Okuda method.

EXPERIMENTAL

The proteins selected were known to vary from less than 0.5 percent to over 1.25 percent cystine, a range that covers most of the known proteins, exclusive of some albumins and keratins. If any variation from method to method is to be expected it would be more apt to occur in proteins with cystine contents of these orders of magnitude than in the keratins with extremely high cystine values. The edestin, arachin, and casein were carefully isolated and highly purified samples prepared in our laboratory. The proteins from halibut, haddock, salmon, round, and sirloin steaks were samples of those previously described and analyzed by Sullivan and Hess (8). The ox-muscle protein and the shrimp protein were prepared by Dr. D. B. Jones, Bureau of Agricultural Chemistry and Engineering. For the cystine determination a suitable amount of the protein, usually 500 mg, was hydrolyzed with (1) 2.0 cc 6N H_2SO_4 for 12 hours; (2) 2.0 cc 20 percent HCl for 8 hours; (3) 2.0 cc 36 percent HCl and 2.0 cc 95 percent HCOOH for 24 hours; (4) 5.0 cc 57 percent HI containing some H_3PO_2 for 16 hours. The temperature of the bath for all the hydrolyses was 125–130°. With the H_2SO_4 and the HCl digestion there was formed considerable humin, soluble and insoluble. With HCl-HCOOH hydrolysis there was soluble humin but only in some few cases insoluble humin. Hydrolysis with HI led to no humin formation. The HCl-HCOOH hydrolysate was concentrated to a syrup on the water bath and the residue was taken up with 10 cc H_2O. This solution and the hydrolysates from procedures (1) and (2) were decolorized by bringing to a gentle boil with 100 mg acid-washed Carbex E. After filtration the carbon was mixed with 5.0 cc hot N HCl, collected on a filter and washed with water. The respective filtrates and washings were brought to pH 3.5 by the addition of 5N NaOH dropwise with stirring, and then diluted to 30 or 25 cc with 0.1 N HCl. The HI hydrolysates were concentrated to a syrup, brought to pH 3.5 and diluted to volume as above.

In the HI hydrolysates only cysteine was present, and the standard for comparison, in the Sullivan method, was a freshly prepared solution of a highly purified cysteine hydrochloride. It is necessary that the cysteine hydrochloride used as a standard be thoroughly evaluated because cysteine hydrochloride may contain water of crystallization or may be somewhat oxidized. As a consequence, too high results will be found for cysteine in the materials under investigation. The results of the analysis of the 10 proteins by the several hydrolytic methods are given in Tables 1 and 2. All results are corrected for moisture and ash and computed as cystine.

TABLE 1.—PERCENTAGE CYSTINE CONTENT: SULLIVAN METHOD

Protein	H_2SO_4	HCl	HCl HCOOH	HI
Halibut	1.04	1.06	1.20	1.15
Haddock	1.19	1.22	1.23	1.28
Salmon	1.13	1.11	1.15	1.23
Sirloin	0.72	0.77	0.78	0.81
Round	0.78	0.82	0.79	0.83
Edestin	1.20	1.23	1.24	1.25
Ox muscle	0.89	0.89	0.94	0.96
Shrimp	0.88	0.90	0.93	0.96
Casein	0.26	0.25	0.28	0.26
Arachin	1.24	1.25	1.26	1.27

TABLE 2.—PERCENTAGE CYSTINE CONTENT: OKUDA METHOD

Protein	H_2SO_4	HCl	HCl HCOOH	HI
Halibut	1.12	1.10	1.17	1.22
Haddock	1.23	1.27	1.27	1.28
Salmon	1.19	1.19	1.20	1.27
Sirloin	0.77	0.77	0.79	0.83
Round	0.80	0.87	0.84	0.84
Edestin	1.23	1.27	1.27	1.29
Ox muscle	0.89	0.89	0.94	0.96
Shrimp	0.87	0.95	0.97	0.96
Casein	0.27	0.28	0.30	0.29
Arachin	1.26	1.26	1.29	1.33

In contradiction to the work of Kassell and Brand, the data given in the tables

show that the cystine values obtained with H_2SO_4 hydrolysis are in agreement with those obtained with HCl hydrolysis (even for edestin) and that there is no evidence of the formation of any material which inhibits the Sullivan method. It may be noted, also, that the Sullivan method and the Okuda method on these hydrolysates give results of the same order of magnitude, and that the results with HCl and with H_2SO_4 are only slightly below those with HCl-HCOOH and with HI. The HI hydrolysates give slightly higher values, a finding that is probably due to the nonformation of humin.

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CHEMISTRY.—*A crystalline sulphur-protein from wheat.*[1]

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For the past two years the Enzyme Research Laboratory has been interested as a unit in the investigation of a series of sulphur-containing substances resembling proteins and extracted from wheat flour by gasoline. Practically every member of the laboratory has contributed to the progress of this research. The object of this paper is to present a summary of the findings to date. Later publications will endeavor to present the data in more detail than would be suitable here.

This work started with the observation of Balls and Hale (1) that extraction of unbleached wheat flour by gasoline or ether removed a nitrogen-containing body that gave tests for cysteine when fresh; for cystine after standing in air. Similar observations were made on barley, oats, and corn. After extraction from flour, much of the sulphur-carrying material could be repeatedly precipitated by ethyl acetate and again dissolved in ether or low-boiling petroleum fractions. This "ethyl acetate precipitate" was insoluble in water and contained nitrogen, sulphur, and phosphorus. On dilution of an ether solution with alcoholic HCl, a material was precipitated that was soluble in water but no longer soluble in fat solvents. This precipitate contained nitrogen and sulphur but no phosphorus. The solvent still held a mixture of lipids containing both nitrogen and phosphorus. This lipid material is now being investigated and will be reported on in due course. The general pattern of the main constituent is that of a phospholipid; it is not, however, lecithin.

A similar precipitate was obtained with acid alcohol from the crude mixture of lipids without prior treatment by ethyl acetate. Both precipitates are evidently mixtures of substances high in nitrogen, but that from the crude material is appreciably higher.

From its content of nitrogen and sulphur and its tendency to dialyze slowly through Cellophane membranes and because solutions thereof did not precipitate with trichloracetic acid, this material was at first thought to be a peptide of high molecular weight. Later experience has shown it to be a mixture, of which one component is a protein of border line magnitude. This protein was prepared as a crystalline hydrochloride and has been subjected to considerable study. Similar crystals have been prepared in the same way, though in smaller yield, from the "ethyl acetate precipitate," but these have not yet been investigated.

Attempts to recombine the protein and the lipoidal material separated by the acid-

[1] Enzyme Research Laboratory Contribution no. 76. Received February 19, 1942. Part of the work reported on in this paper was done under a grant from the Special Research Funds.

alcohol treatment have been unsuccessful. The existence of compounds of lipid and protein, however, would account for the ready solubility of the protein portion in gasoline even after partial purification had removed most of the fats, sterols, and other concurrent substances that were in the original extract. It seems reasonable to suppose that a combination existed in the original plant material, and if this is so, the crystalline protein is the first known fragment of a lipoprotein to be obtained in a pure state.

The data of this paper were obtained with crystals made directly from the crude extract, omitting the precipitation by ethyl acetate. The substance was crystallized thrice, with removal of the mother liquor each time. A detailed report of these experiments has been submitted for publication elsewhere by Balls, Hale, and Harris (2).

Freshly milled (unbleached) patent flour was extracted in a large percolator with high-grade petroleum ether. Much of the solvent was next removed from the extract by distillation in vacuum, but enough was allowed to remain so that the extract was still fluid. This extract was then stored at $-1.5°$ for several weeks. The sterols that precipitated during storage were then removed by centrifuging in the cold. The supernatant liquid was diluted with an equal volume of ether and then with 3 volumes of cold 1 N HCl in absolute ethyl alcohol. After standing 1 hour at 0° the precipitate formed by the addition of acid alcohol was separated in a refrigerated centrifuge and repeatedly washed by centrifuging first with absolute alcohol and finally with dry ether. The washing was continued until the solvents dissolved no more material from the precipitate. The residue was then dried in vacuum. About 25 grams of material were obtained from a barrel of flour. This amount of the crude material (which is comparable to that described in our first paper), was dissolved in 100 cc of water, and 300 cc of absolute alcohol was added thereto. A precipitate that formed on addition of the alcohol was centrifuged out, and the supernatant liquid was evaporated first on a water bath and finally to dryness in vacuum over P_2O_5. This residue weighed 16.8 grams.

Fifteen grams of the residue were dissolved in 25 cc of water, 225 cc of absolute alcohol then added, and the mixture allowed to stand for 4 hours at about 5°. A precipitate was formed that appeared under the microscope to consist entirely of crystals (Fig. 1). After removal and drying, these weighed 4.10 grams. Recrystallization was done in the same manner as the step just described. The data of Table 1 show the constancy of composition after recrystallization.

Fig. 1.— Crystals of peptide, ×300.

TABLE 1.—CONSTANT COMPOSITION AFTER RECRYSTALLIZATIONS (MATERIAL PRECIPITATED DIRECTLY FROM CRUDE EXTRACT)

Number of crystallizations	N	Cl	S
	Percent	*Percent*	*Percent*
One	16.20	6.64	4.40
Two	17.37	6.57	4.46
Three	17.28	—	—
Four	17.30	6.56	4.44

The crystals are definitely those of a hydrochloride. An aqueous solution containing 1 mg of substance per cc was at pH 3.9 and contained chlorine precipitable by silver nitrate. The total chlorine found was 0.185 mole per 100 grams, whereas nitrogen present as free amino groups determined by the Van Slyke apparatus was 0.118 mole per 100 grams. The proportion of chlorine to free amino groups is thus very nearly 3:2.

Approximately two-thirds of the molecule of this protein has been identified after the usual acid hydrolysis. Table 2 shows the composition as found so far, expressed in equivalents. If the constituent occurring to the least extent (tyrosine) is assumed to be present once in the molecule, a molecular weight of about 6,000 is indicated. The rate of diffusion through a porous membrane from a solution containing 0.5 M NaCl into a solution of the same salt concentration indicated a molecular weight of 10,200, or roughly twice the value calculated from the tryosine content. Both figures must be very approximate, but they are quite in accord with the observed behavior of the substance, which forms only a slight turbidity in warm five-percent aqueous trichloracetic acid.

TABLE 2.—CONSTITUTION OF THE CRYSTALLIZED SUBSTANCE[1]

Constituent	Percent
Chlorine	6.57
Sulphur	4.42
Nitrogen, total	17.35
Nitrogen, free NH_2 groups	1.65
Constituent	**Proportion of equivalents (tyrosine = 1.00)**
Arginine	6.9
Cystine	3.9
Tyrosine	1.0

[1] Of the total nitrogen, 59.6 percent, or nearly two-thirds, is accounted for by arginine, cystine, and tyrosine.

The substance thus appears to be on the border line between proteins and high molecular peptides, and on account of the large content of arginine it resembles most the protamines described by Kossel. Since these similarly basic bodies are usually regarded as the simplest of the proteins, our material is probably better classed as a protein than as a peptide.

The substance is remarkable for its high content of cystine. It was found that 95 percent of the sulphur (so probably all of it) is present as cystine in the crystals, although some existed in an SH form in the original plant material. The new protein is thus capable of oxidation and reduction. Attempts to crystallize the reduced form have failed, apparently because the reduction of all the cystine was not accomplished, and a mixture of reduction products resulted. Nevertheless, the ability of the protein to undergo reduction and oxidation makes it biologically very reactive.

Toxicity to tissues and bacteria.—The work of Stuart and Harris (3) has shown that the crystalline protein, like Dubos's gramicidin (4), is specifically poisonous to certain bacteria. Gram positive bacteria and yeasts were found to be most vulnerable. Ordinary baker's yeast was killed when 5 γ of protein hydrochloride was present per cc of a medium that contained sucrose and the usual nutrient inorganic salts. Growth was prevented by a concentration as low as 1 γ per cc. These investigators advance the opinion that this protein is the yeast-poisonous material long known by brewers to exist in many grains and particularly in wheat.

That toxicity is not confined to microorganisms has been shown by Coulson, Harris, and Axelrod (5). Rabbits were killed in a few minutes by intravenous injections of 1.6 mg per kg, while mice and guinea pigs were killed by intraperitoneal injections of approximately 10 times this dose. Large quantities of the substance, however, could be repeatedly fed by mouth without any noticeable effect, either on the welfare of the animals or on their subsequent susceptibility to injection.

Very small amounts of the protein dissolved in Tyrode's solution produced marked and sustained contraction of the uteri of virgin guinea pigs. The pharmacological picture resembled that produced

by histamine, rather than by proteins, in that repeated doses, after removal of the previously applied solution, caused repeated sets of contractions, thus showing that the tissue was not desensitized by the first application. 50 γ of protein in 50 cc of solution produced contractions similar to those caused by 10 γ of histamine in the same volume.

The effect is not due to histamine or apparently to any small toxic group in the protein structure, for when the protein was subjected to digestion by crude papain and H_2S, the toxicity disappeared. The digestion increased the free amino nitrogen (Van Slyke) in an amount representing the break of only about one-third of the peptide linkages presumed to be present, so that the molecular size of some of the nontoxic end products may still have been considerable. Comparable experiments showed furthermore that this enzyme mixture had no effect on the toxicity of histamine (*i.e.*, did not deaminate or otherwise destroy it).

Effects with certain enzymes.—The oxidative capacity of the new protein in its S-S form is shown by the inhibition of chymopapain, a proteolytic sulphur-containing protein active only in the SH form (6). Buffered mixtures at (pH 4) of crystalline chymopapain and the wheat protein were tested with respect to milk-clotting power, which was found to diminish at a rapid but measurable rate (Fig. 2).

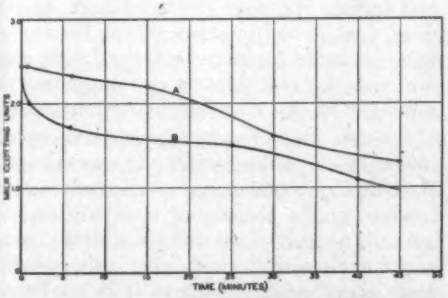

Fig. 2.—Upper curve, rate of inhibition of crystalline chymopapain in a solution of 214 milk-clotting units (active without CN) per cc of 0.1 M ammonium chloride buffer (pH 7.5±0.2), containing 0.3 mg per cc of crystalline flour protein. Lower curve, same but with twice the amount of protein.

Chymopapain is moreover unable to digest the oxidized form of this wheat protein. After saturating the mixture with hydrogen sulphide digestion proceeds rapidly, as with crude papain, until about one-third of the computed number of amino acid linkages have been hydrolyzed. This experiment shows furthermore that while the enzyme is inhibited it is not destroyed and may be reactivated by reduction, thus indicating that the effect of the protein on the enzyme is an oxidation similar to that produced by large amounts of cystine.

Another property of the wheat protein, recently observed by Axelrod and Kies, of the Enzyme Research Laboratory, is its power to inhibit carotene oxidase. This enzyme is a constituent of many legumes and catalyzes the destruction of all carotinoid pigments so far tested. It is thought to acclerate the destruction of carotene and other pigment precursors of vitamin A (as well as of vitamin A itself)[2] when plant tissues are stored or when dried without prior pasteurization. The enzyme may be readily demonstrated by adding a few drops of a water extract of soybean meal to an acetone solution of carotene that must contain also some unsaturated fat and that has been previously diluted with phosphate buffer (pH 6.4). The color of the carotene rapidly fades, provided only that the water present has not been deprived of its dissolved oxygen. Double bonds in the fatty acid structure participate in the reaction at the end of which the fat shows an increased peroxide number. The enzyme is therefore often referred to as a lipooxidase, whose effect on carotene is an indirect one.

The presence of very small amounts of the protein hydrochloride in a suspension of carotene and fat in buffer was enough to prevent the action of large doses of soybean

[2] The destruction of carotene by the soybean enzyme was found by Frey, Schultz, and Light (7) to destroy also all appreciable vitamin A activity. Dr. E. M. Nelson, Chief, Vitamin Division, Food and Drug Administration, has also found that destruction of the vitamin A activity results from oxidation of carotene with our enzyme preparation. The Enzyme Laboratory is greatly indebted to Dr. Nelson and Dr. C. D. Tolle for this important information.

extract added subsequently.[3] The inhibition, however, requires the presence of an electrolyte, but not necessarily of a buffer. Sodium chloride was sufficient. Other proteins, for example egg white, chymotrypsin, and chymopapain, also inhibit the oxidation. The quantity required of these proteins is much larger, however, so that the effect of the flour protein appears to be outstanding. Furthermore, the inhibition observed with other proteins is independent of the amount of unsaturated fat mixed with the carotene, whereas in the case of the flour protein it is not. Inhibition by the new protein may be overcome by increasing the fat present in the carotene mixture. The quantity of fat needed was found to be roughly proportional to the amount of protein present. The substitution of petroleum oil for the additional fat was without effect, which indicates the inhibition is not altogether a surface matter.

This inhibition, however, is peculiar in that it does not occur if the protein is added first to the soybean extract rather than to the carotene-buffer mixture. The reason for this behavior is unexplained and in all probability will remain so until preparations free from other enzymes are available. There is some evidence that the destruction of the inhibiting power of the flour protein may be due to proteolysis. The soybean extract we have used contained a proteolytic enzyme, and proteinases such as commercial trypsin and crystalline chymotrypsin were found to destroy the inhibitory effect of the flour protein.

In view of these observations, wheat flour itself might be expected to act as an inhibitor, and this was found to be the case, not only with a suspension of flour in water but also with an aqueous extract thereof. Prior digestion of either preparation with chymotrypsin removed the inhibitory property. This is of interest because soybean meal has been used in bread making for bleaching the yellow color normally imparted to bread by the flour. It has long been known that this bleaching was due to a destruction of carotinoid pigments (chiefly lutein) in the flour. The commercial use was in all probability the first recognition of this oxidizing enzyme.

It is obvious that when soybean meal is added to bread dough, some mechanism destroys the inhibitor originally present in the flour. Since soybean meal and flour are both known to contain proteinases, it may be that the destruction of the yellow color in bread dough is preceded by a proteolysis. It must be remembered that the flour protein, inhibitory to carotene oxidase in the S-S form, is found in flour also in the SH form. In this form it is an activator of any papainlike enzyme present, including the proteinase of wheat.

It is well known that the behavior of carotene oxidase, particularly with respect to the necessity for the presence of unsaturated fats with the carotene, points to the classification of this enzyme as a lipo-oxidase. Moreover, Sumner and Dounce (8) and Sumner and Sumner (9) have shown that soybean meal and oxygen are able to increase markedly the peroxide groups in fat. This was shown experimentally by stirring air into a mixture of fat, soybean meal, and buffer. We have observed here, moreover, that in the presence of the flour protein, peroxide formation in the fat is also diminished. The protein is therefore an inhibitor of the enzymic oxidation of fat.

Because the protein forms a reversible oxidation-reduction system, it was thought that it might also serve as an antioxidant for fats in the absence of an oxidizing enzyme. The previously described "ethyl acetate precipitate," containing this protein and other bodies similar to it in combination with lipids that render the complex soluble in ether and gasoline, is best suited for a test, because the complex is somewhat soluble in fats and oils, whereas the protein portion is not. Dr. M. B. Matlack, of the Enzyme Research Laboratory, has made an

[3] A solution of carotene and corn oil was made in acetone containing 10 percent of absolute alcohol. This solution contained 43 γ of carotene and 100 γ of corn oil per cc. One cc of the solution was placed in a dry flask and diluted with 10 cc of water and 0.5 cc of 0.6 M phosphate buffer (pH 6.5). One-tenth cc of an aqueous extract of soybean meal (2.5 g per 100 cc water) usually decolorized half the carotene present in less than one minute. In the presence of 20 γ of the protein hydrochloride, no measurable bleaching was observed in this system during 30 minutes.

investigation of the effect of this material on the speed at which corn oil turns rancid. Judged from the peroxide number of the oil after exposure to light and air for many days, the lipoprotein compound is a good antioxidant. Judged by organoleptic tests, however, the oil was not only not protected but may even have become more susceptible (Fig. 3). The matter is thus not decided. It

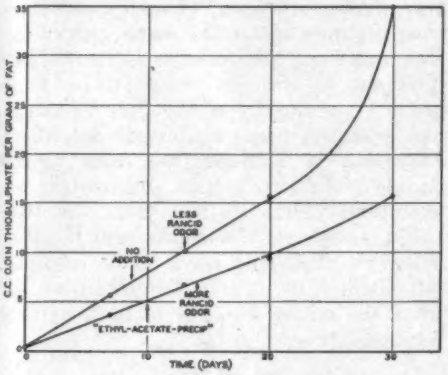

Fig. 3.—Increase in peroxide number of corn oil kept at room temperature (in daylight).

is not improbable that the protein can catalyze the formation of aldehyde and/or ketone bodies at the expense of the fat peroxides, thus causing a low peroxide value but considerable organoleptic rancidity.

Summary.—The composition of a crystalline protein hydrochloride isolated from wheat flour has been partially worked out. There is evidence that this protein is an oxidized fragment of what in the original plant tissue was a cysteine-containing lipoprotein. In the oxidized state, after crystallization, this substance lies on the border line between proteins and similarly constituted bodies of lower molecular weight. It resembles the protamines, being rich in arginine; but unlike the hitherto described protamines, it contains much cystine.

About two-thirds of the molecule (estimated molecular weight, 12,000) has been identified as consisting of arginine, cystine and tyrosine (in order of frequency).

This protein is particularly toxic to yeasts. It may be the yeast-poisonous substance long known to be present in several grains. It is also toxic when injected into small animals but has no effect by mouth.

The protein is very inhibitory to certain enzymes. Chymopapain is evidently inhibited reversibly by oxidation, presumably at the expense of the cystine in this protein. The protein also protects carotene from oxidation by the carotene oxidase that occurs in many vegetables and seeds.

As a protein, this substance is readily decomposed by certain proteolytic enzymes. Its inhibitory power against the carotene (fat) oxidase disappears on digestion as does its toxicity. The question remains whether the enzymic oxidation of vitamin A and the precursors thereof, inhibited in the plant by substances such as this flour protein, may occur after proteolytic enzymes have destroyed the inhibitor. Because in the plant the protein is in the reduced state, it is a natural activator of the proteinases of the papain type that are almost always present. Should conditions favor proteolysis (and the death of tissue does so), carotene and thus potential vitamin A would be destroyed by a simple oxidative side-reaction.

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BOTANY.—Linanthastrum, *a new West American genus of Polemoniaceae.*[1]

JOSEPH EWAN, University of Colorado. (Communicated by EDGAR T. WHERRY.)

The perennial montane genus *Linanthastrum* as here established represents a small series of Polemoniaceae of conceivably greater antiquity from the phylogenetic standpoint than the related annual genus *Linanthus*. The present distribution of the genus *Linanthastrum* constitutes what may well be a relict pattern of boreal origin, occupying as it does old mountain masses and tablelands of western North America. This genus is most closely related morphologically to *Linanthus*, but its more northern and montane-to-subalpine distribution suggests a different origin from that genus of more Sonoran tendencies, if one may borrow vegetation-terms from two different schools of ecologists. Furthermore, *Linanthastrum* differs from *Linanthus* in that the calyces are not scarious below the sinuses (cf. Fig. 2)—a character of reliable constancy in the rather natural genus *Linanthus*, when the present perennial group is removed from it. *Leptodactylon* is its nearest morphological ally on the other side; from this genus *Linanthastrum* differs in having scarcely or not at all pungent, closely opposite, falsely whorled leaves, and very dissimilar calyx. Though *Linanthastrum* occupies about the same geographic region and ecologic niche as *Leptodactylon*, it is not so strongly xerophytic as that genus. A phylogeny of the Polemoniaceae has recently been suggested[2] in which *Linanthus* is a derivative from *Leptodactylon*, the two genera constituting an evolutionary line distinct from the true *Gilias*, *Langloisia*, *Ipomopsis*, and *Hugelia*. Wherry's phylogeny needs to be modified but slightly to include *Linanthastrum*, in what the author believes to be a natural relationship:

[1] Received October 28, 1941.

[2] WHERRY, EDGAR T. *A provisional Key to the Polemoniaceae.* Bartonia 20: 17. 1940.

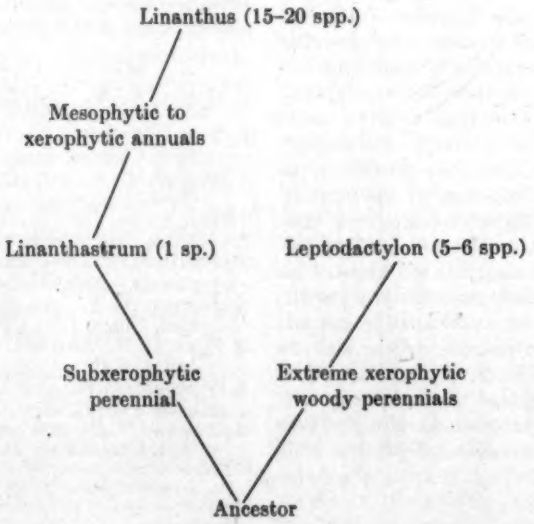

Fig. 1.—A putative phylogeny for three genera of Polemoniaceae: *Leptodactylon*, *Linanthastrum*, and *Linanthus*; in all these the chromosome number $n = 9$.

HISTORICAL NOTE

Thomas Nuttall first recognized the present genus *Linanthastrum* in essentially the sense here defined, naming it *Siphonella*. This was never published by him, but Asa Gray cited the binomial *Siphonella montana* when publishing *Gilia nuttallii* (1870). By his choice of specific name Gray evidently

Fig. 2.—*Linanthastrum nuttallii* (Gray) Ewan: Habit sketch from *Payson & Armstrong 3458*, Wyoming, ×½. Calyces: Upper, *Linanthastrum nuttallii;* middle, *Leptodactylon pungens* (Torr.) Nutt.; lower, *Linanthus androsaceus* (Benth.) Greene. Intercostal membranes stippled.

wished to record his recognition of Nuttall's part in the characterization of the species. Gray did not designate a type in his original description, for he did not practice the "type basis concept" of the present day. However, Nuttall's contribution toward establishing the concept of *Gilia nuttallii* must be borne in mind when fixing the type of that species. When describing the species Gray placed it in a section Siphonella—taking up Nuttall's manuscript generic name—which he considered to be related to the section Leptodactylon. (Dalla Torre and Harms (1907) erroneously date the establishment of the section Siphonella from the Botany of California (1880) rather than 1870.) Up to 1904, then, our plant was treated as a species of *Gilia*. But in that year Greene's manuscript herbarium name *Linanthus nuttallii* was published.[3] Milliken did not accept *Leptodactylon* as a genus of the Californian flora, and no comment was made by her as to the anomalous nature of *Linanthus nuttallii* within the genus *Linanthus*. When Rydberg in 1906 resurrected *Leptodactylon* as a genus he included *Gilia nuttallii* therein. (Though proposed by Hooker and Arnott in 1841, Bentham placed *Leptodactylon* in the genus *Gilia* as a section in 1845, and was widely followed.) After Rydberg, *Linanthastrum* was considered a member of the genus *Gilia* by Brand (1907), of *Leptodactylon* by Jepson (1925), and of *Linanthus* by both MacMinn (1939) and Wherry (1940). From this summary of the taxonomic history of *Linanthastrum* it is clear that we are dealing with an anomalous group, fitting poorly into our present alignment of the gilioid genera.

Linanthastrum, genus novum

Siphonella Nutt. ex Gray, Proc. Amer. Acad. **8**: 267. 1870, as a synonym.

Herba perennis caulibus e basi lignescente suffrutescentibus plurimus simpliciusculis erectis subscopariis; foliis 3–7 partitis, laciniis acicularibus non pungentibus brevo-mucronatis integerrimis enervosis; floribus subspeciosis in acillaris superioribus, calycium tubis campanulatis brevibus sinubis inter dentes non scarioso-membranaceis; staminibus sub fauce insertis filamentibus glabris.

Tufted puberulent perennials with rather virgate simple stems, the upper internodes mostly shorter than the leaves; leaves appearing as if whorled, the blades 3–7 parted, the segments linear to acicular, entire, the midnerves obscure. Flowers borne in the upper axils, scarcely exserted from the tufted leaves but somewhat showy. Calyx campanulate, the tube short, not scarious-membranous below the sinuses between the subulate teeth. Corolla-tube funnelform, pale yellow, the lobes 5, obovate, rounded, cream to white or very pale blue. Stamens inserted just below the throat, the filaments glabrous. Pistil included, nearly equalling the tube. Seeds 2–4 in each locule. Fig. 2.

Type species: *Linanthastrum nuttallii* (Gray) Ewan.

Linanthastrum nuttallii (Gray) comb. nov.

Based on *Gilia Nuttallii* Gray, Proc. Am. Acad. **8**: 267. 1870, in turn based on Nuttall coll. from "R[ocky] Mts. Bear R[iver] hills" in

[3] MILLIKEN, JESSIE. *A review of Californian Polemoniaceae.* Univ. Calif. Publ. Bot. **2**: 54. 1904.

Acad. Nat. Sci. Philadelphia and in Gray Herbarium a fragment labeled as from "Hb. Ac. Phil." According to the map of Nuttall's travels given by Pennell[4] the type locality would be in the region of Caribou and Bannock Counties, Idaho. There might be some justification for selecting one of the several collections cited by Gray in the original description as the type, but the present author construes these to be paratypes and has so treated them beyond. Gray's choice of specific name seems to me to denote his intentions clearly.

Paratypes: *Fremont*, without loc.; *Anderson*, from near Carson City, Nev.; *Brewer 2042*, Silver Mountain, Sierra Nevada, Calif. (cf. Jepson, Madrono **2**: 85. 1933, on this mining town); and *Watson 907*, "E. Humboldt Mts.," Nev., which are the present Ruby Mountains, central Elko County (cf. Linsdale, Pacific Coast Avifauna **23**: 16. 1936). Gray has noted on sheet of *Brewer 2042*, "Filaments unusually long" and "between *S. montana* and *S. parviflora*." This would indicate that he regarded this collection as somewhat exceptional, as C. A. Weatherby has suggested to the author. However, Wherry (in litt.) considers that these paratypes are "all conspecific, but may represent ecological forms of one another."

Linanthus Nuttallii (Gray) Greene ex Milliken, Univ. California Publ. Bot. **2**: 54. 1904.

Leptodactylon Nuttallii (Gray) Rydb., Bull. Torr. Club. **33**: 149. Mar. 1906; practically simultaneously published in Colorado Agr. Expt. Stat. Bull., Flora of Colorado, **100**: 279. Introduction dated March, 1906, but apparently not issued until later that year.

Gilia Nuttallii var. *montana* (Nutt.) Brand in Engler, Pflzr. **IV. 250**: 125. 1907, based on *Siphonella montana* Nutt. ex Gray. Epithet used by Brand to designate the typical phase of the species.

Gilia Nuttallii var. *parviflora* (Nutt.) Brand, *loc. cit.*, based on *Siphonella parviflora* Nutt. ex Gray, l.c., as synonym, and in turn based on Nuttall coll. from "Bear R. hills" acc. fragments at both Gray Herb. (ex Brit. Mus. Nat. Hist.) and Acad. Nat. Sci. Philadelphia. Wherry (in litt.) states that the differences between this collection and that of *S. montana* are "so slight that it is strange that Nuttall named them differently. His "*Siphonella montana*" has the leaves essentially glabrous, his "*S. parviflora*" has them more or less pilose. I can not see any difference in the size of the flowers which would have suggested the name *parviflora*."

Illustrations: Watson, Botany Fortieth Parallel, pl. 25, fig. 8, 1871, presumably based on *Watson 907* from Nevada, a paratype, is good. MacMinn, Illus. Man. California Shrubs, fig. 532, 1939, presumably drawn from either a Sierran (e.g., Lake Tahoe) or Cascadean specimen, but not indicated.

Rather bushy perennial from a woody branching suffrutescent crown, the stems several, simple, 15–20 cm tall, puberulent, straw-colored; leaf segments 3–7, flat, 1.0–1.5 cm long, strictly linear or actually less than 1 mm broad, glabrous or glabrate, sparingly ciliolate, the leaves overlapping due to the relative shortness of the internodes especially in the upper parts (except in plants of southernmost portions of its range), thus forming chara-like tufts near the tips of the stems, those in the lower half soon withering; calyx 8–10 mm long, the tube 2 mm long, the teeth lance-subulate, shortly acute, puberulous; corolla-tube yellow, 8–9 mm long, glabrous within, pubescent with curling hairs without, the lobes 4–5 mm long, white or pale, somewhat chalky, blue; capsule narrowly obovoid, 5 mm long, smooth.

Subalpine meadow borders or less often among rock outcrops and about the margins of scree slopes, always in well-drained, often granitic soils. Washington and northern Idaho south along the Cascades and Sierra Nevada to southern California, the mountains of northern Nevada and Utah, and south along the Rocky Mountains to central Colorado. A taller more slender form differing in greater pubescence occurs in New Mexico, northern Arizona, and (?) in Baja California.

Representative collections (at Univ. Colorado unless indicated): WASHINGTON: Lewis County: Eagle Peak, 5,600 ft., Tatoosh Range, *Ewan 10601;* Goat Mts., *Allen 119* (ANSP)[5]. Kittitas County: Mts. n. Ellensburg (Piper, Fl. Wash. 462). Columbia County: Blue Mts. (Piper, l.c.). IDAHO: Ridge s. Pole Mt., 5,000 ft., *Epling et Kempf s. n.* Valley County: Gold Fork lookout, Sawtooth Mts., 8,000 ft., *J. W. Thompson 13763*. Custer County: Robinson Bar, 25 VI 1931 *Wherry* (Univ. Pa. Herb.). OREGON: Wallowa County: Wallowa Mts., *Ownbey 1843* (Univ. Pa. Herb.). Crook County: *Peck 9657* (ANSP). Harney County: Steins Mt., 8,000–9,000 ft., 1 VII (no year) *Percy Train*. UTAH: Salt Lake County: *Garrett 1559a* (ANSP). CALIFORNIA: Humboldt County: 28 mi. se. Orick, *S. W. Hutchinson 4152*. Modoc County: Little Lily Lake, Pine Creek, Warner Mts., *Wheeler 8789* (ANSP). Mono County: Mammoth Lakes P.O., *Constance 2423* (ANSP); Leevining Canyon, *Benson 3767* (ANSP); Inyo Mts. (Coville, Death Valley Rept. 156). Inyo County: Bishop, 1928, *S. W. Hutchinson s. n.* Wyman Creek, White Mts., *Duran 3048* (Univ. Pa. Herb.). Tulare County: Farewell Gap, *Culbertson 4536* (ANSP); Mt. Whitney (Brand, *op. cit.*). San Bernardino County: Foxesee Creek, *Parish 3686* (ANSP). Riverside County: El Toro, Santa Rosa Mts. (Milli-

[4] PENNELL, FRANCIS W. *Travels . . . of Thomas Nuttall.* Bartonia **18**: pl. 3. 1936.

[5] Abbreviation for Academy of Natural Sciences of Philadelphia.

ken, *op. cit.*). NEVADA: Douglas County: Zephyr Point, 6,300 ft., Lake Tahoe, *Mason 12161*, Elko County: East Humboldt Mts. (i.e., Ruby Mts.), *Watson 907* (ANSP). WYOMING: Lincoln County: Sheep Mt., Snake R. Range, *Payson et Armstrong 3458*. Sublette County: Gros Ventre Mts., *E. B. et L. B. Payson 3028*. COLORADO: ?Lake County: s. slope Fremont Pass, *A. et R. Nelson 145*. Eagle County: w. slope Tennessee Pass, 10,400 ft., *Schmoll 1545;* Oro City, 10,800 ft. (Wheeler Survey Rept. 199). Routt County: Steamboat Sprs., 6,500 ft., VII 1891, *Eastwood*. Jackson County: (formerly part of Larimer County.) Rabbit Ears, *Goodding 1540*. Gunnison County: Ragged Mt., 11,700 ft., (Rydberg, Fl. Colo.). Mineral County: Near Pagosa Peak, San Juan Range (Rydberg, l.c.); 10 mi. e. Wolf Creek Pass on Continental Divide, 12,000 ft., *Penland 1154* (Colo. Coll. Herb.). Custer County: Venable Lake, Sangre de Cristo Mts., *M. Marriage et P. Johnson* 14 VII 1932 (Colo. Coll. Herb.). Bent County: Robinson, 4,007 ft. (Rydberg, l.c., presumably pls. carried down on flood waters of Arkansas R.).

Linanthastrum nuttallii subsp. **floribundum** (Gray) comb. nov.

Based on *Gilia floribunda* Gray, Proc. Amer. Acad. **8**: 267. 1870, in turn based on *Coulter 454* "California, probably on se. borders." Likely from vicinity of Warner Hot Springs, San Diego County, where Thomas Coulter is known to have passed. Paratypes: *E. W. Morse* coll., 1866, from 50 mi. s. San Diego, Baja California and *Coues et Palmer* coll., 1865, from "pine woods of Arizona," according to label from Ft. Whipple, 5 VIII 1865, numbered *98* and annotated "fl. white; throat yellow; scent delicate." (For a descriptive account of Coues's visit to Fort Whipple see the Ibis (ser. 2) **2**: 259–275. 1866.)

Linanthus floribundus Greene ex Milliken, Univ. California Publ. Bot. **2**: 55. 1904.

G. Nuttallii var. *parviflora* (Nutt.) Brand subvar. *floribunda* (Gray) Brand in Engler Pflzr. **IV. 250**: 125. 1907.

G. Nuttallii var. *floribunda* (Gray) Munz, Man. S. California Bot. 399. 1935.

Leptodactylon floribundum (Gray) Tidestrom, Proc. Biol. Soc. Washington, **48**: 42. 1935.

Linanthus Nuttallii var. *floribundus* (Gray) McMinn, Illus. Man. Calif. Shrubs 446. 1939. Illustration: MacMinn, *op. cit.* fig. 533.

Plants of more open habit, the stems slender, generally taller, rather wiry, densely clothed with simple subfiliform or few-lobed leaves; flowers hardly crowded or glomerate, the uppermost distinctly pedicellate, the corollas smaller, 10–15 mm long; seeds usually 4 in each locule (always 2 in each locule in the typical subspecies of *L. nuttallii, fide* Gray and Brand).

Dry brushy slopes in clearings of the chaparral. New Mexico south to Chihuahua, Mexico, west to Baja and southern California, but apparently local.

Representative collections (as above, at Univ. Colorado unless otherwise indicated): NEW MEXICO: Lincoln County: Tularosa Creek, White Mts., 18 VIII 1899, *Wooton*. Catron County: 15 mi. s. Luna, 6,700 ft. *C. L. Hitchcock et al. 4482*. ARIZONA: Yavapai County: Fort Whipple. MEXICO: Chihuahua: Pachaco, *Hartmann 682* (ANSP); Baja California: paratype cited above. CALIFORNIA: San Diego County: Warner's Rch., 3,165 ft., VI 1927, *S. W. Hutchinson s. n.;* Descanso, 20 VI 1932, *Epling et al.;* Cold Spring, 21 VI 1932, *Epling et al.* Riverside County: Coyote Canyon, *fide* Milliken, *op. cit.;* Elsinore, *ibid.;* San Jacinto (*ibid.*); Santiago Peak, Santa Ana Mts., *Abrams 1809* (ANSP).

In an occasional individual collection *Linanthastrum nuttallii floribundum* may appear fully distinct from the typical subspecies, but when a series is studied really satisfactory characters for a key can not be found. Though the two have not been found growing together, the more southern subspecies occupies the more xeric habitats at rather distinctly lower elevations. In the Santa Rosa Mountains of southern California the two subspecies approach each other closely; nevertheless, the two may even there show ecologic preferences. It cannot be finally declared that there are not two species in this genus, as held by Asa Gray, Greene and Milliken. The herbage of the typical subspecies is distinctly hay-scented and the flowers of both it and *L. nuttallii floribundum* are delicately fragrant.

SUMMARY

Linanthastrum is established as a segregate genus of the gilioid complex, most closely related to *Linanthus*, but differing from that rather natural genus in its habit-form, in the calyces not being scarious below the sinuses, in its perennial duration and its more northern, usually upper montane or subalpine, distribution suggestive of a different origin. From *Leptodactylon* it differs in having scarcely or not at all pungent, closely opposite, falsely whorled leaves, as well as in calyx-features. This group of one species with two subspecies is more naturally disposed among the gilioid members of the Polemoniaceae when admitted as a small genus of transitional morphology, sharing as it does certain characters of both *Linanthus* and *Leptodactylon*.

BOTANY.—*Marine algae of Hong Kong, II: The genus* Catenella.[1] C. K. TSENG, University of Michigan. (Communicated by H. H. BARTLETT.)

Catenella Grev. (1830) is a genus of small, creeping, dark-purplish algae that form intricate, overlapping patches on mangroves, other marine seed-plants, and muddy rocks in sheltered places, especially the salt marshes between tide marks. It is chiefly tropical and subtropical in distribution, but one of its species occurs also in temperate seas.

Generally, members of this genus have decumbent, creeping, cylindrical or subcylindrical, irregularly branched, stoloniferous parts from which issue the more regularly, pinnately or dichotomously to polychotomously branched upper parts, which are, in typical forms, regularly and deeply constricted into subcylindrical to strongly compressed, lomentlike segments. The attachment of the fronds to the substratum is by means of primary, stout, discoid holdfasts issuing from the stolon and also by secondary haptera, issuing regularly or irregularly from the upper segments. Internally the segments are each composed of a very lacunose medulla of loosely interlacing and anatomosing longitudinal filaments that originate from a central axis and give rise toward the periphery to dichotomously branched, moniliform filaments, which unite firmly to form a compact cortex. Cystocarps are generally solitary and sessile on shortened, terminal segments, each provided with a terminal pore. Spermatangia, consisting of small cell groups immersed in the cortical tissue, are found on swollen segments. Tetrasporangia are oblong, transversely zonately divided, and scattered in the cortex between the moniliform filaments; they are aggregated in terminal segments.

The type of the genus is *Catenella opuntia* (Good. et Woodw.) Grev., now known as *Catenella repens* (Lightf.) Batt., from Tenby, South Wales, which is now found to be widely distributed in most of the warmer seas. Since the proposal of this genus by Greville in 1830, seven other species have been added. One of these, *C. pinnata* Harv., is now regarded as synonymous with *C. repens*, whereas three others, *C. oligarthra* J. Ag., *C. procera* J. Ag., and *C. major* Sond, are found to belong to other genera and are excluded. There are now four recognized species of *Catenella: C. repens*, *C. fusiformis* (J. Ag.) Skottsb., *C. impudica* (Mont.) J. Ag., and *C. nipae* Zanard. To these is to be added another, *C. subumbellata*, described as new in the present paper.

In the past there has been confusion in the naming and separation of these few species. Rather recently, Post (1936) made a revisional study of the genus and cleared up the situation. The nature and relative position of the haptera have been used as the chief distinguishing characteristics; others, such as the differentiation of the long and dwarf shoots, the branching method, and the shape of the segments, have also been used.

Because of their peculiar habitat, different from that of most marine algae, and their relatively small and inconspicuous fronds, members of this genus are not often collected, although they are actually widely distributed in the warmer seas. None has ever been reported from China so far. Quite recently the writer and his collector secured four samples which, when carefully studied and analyzed, are found to represent three species, including one new to science. The following key serves to distinguish them:

A. Haptera equivalent to entire independent segments, developed at nodes. . . . . 1. *C. impudica*

AA. Haptera formed by distal ends of segments.

[1] Received December 31, 1941. The writer planned this series of papers for publication in the Journal of the Hong Kong Fisheries Research Station, and the first number, entitled *Historical survey and list of recorded species*, was issued September, 1940, in Vol. 1, No. 2, pp. 194–210. On account of the fall of Hong Kong the Station and its Journal will now presumably be suspended for an indefinite period, and for the time being the remaining papers of the series are therefore being published wherever circumstances permit.

B. Frond stout, regularly dichotomously to trichotomously branched, with stout, oblong segments; haptera terminal or seemingly subterminal on segments.....2. *C. nipae*

BB. Frond slender, irregularly unilaterally, subpinnately or, more generally, subumbellately branched, with linear-elliptical segments; haptera situated in center of verticels.....3. *C. subumbellata*

1. Catenella impudica (Mont.) J. Ag.

Figure 1

Catenella impudica J. Ag. Sp. Alg. 2 (2): 701. 1852; Möbius, Bearb. Bras. Alg. 335, pl. 10, figs. 16–21. 1889; De-Toni, Syll. Alg. 4: 320. 1897; Post, Notizen 66. 1936.

Lomentaria impudica Mont. Pl. Cell. Cent. 197. 1840; Kütz. Sp. Alg. 863. 1849; Kütz. Tab. Phyc. 15: pl. 92, figs. a–c. 1865.

The frond of this species forms a decumbent patch about 1.5 cm high and several centimeters broad. It is distinctly articulate, repeatedly dichotomously or trichotomously branched. The segments are deeply constricted at the nodes, subcylindrical when young but greatly compressed when older, and elliptical

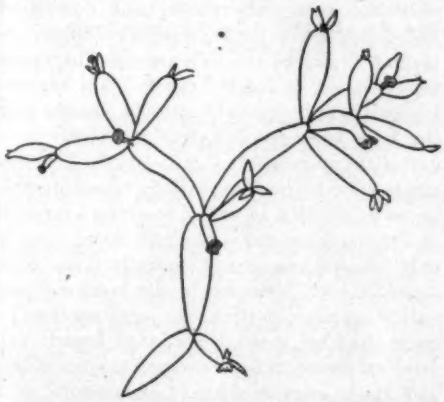

Fig. 1.—Habit sketch of *Catenella impudica* (Mont.) J. Ag. About ×4.

or oblanceolate, rarely oblong, in shape. Mature segments are as much as 1.5 mm broad and are generally three to four times as long. The haptera represent entire independent segments, which remain linear-subcylindrical in shape and become definite in growth as the apices are transformed into adhesive, broad discs. They always occur at the deeply constricted nodes, generally between two other segments of the same order (cf. Fig. 1). The materials collected are all sterile.

HABITAT: Forming decumbent patches on trunks of mangroves in sheltered salt marshes, in the littoral region, Aberdeen, Hong Kong Island, in July 1941 (*Taam A151*).

DISTRIBUTION: Sinnamary, French Guiana, northern South America (type locality), and nearby regions; the West Indies, Brazil, Africa, India, and the Malay Archipelago.

Catenella impudica can be easily recognized by its regularly, repeatedly, predominantly trichotomous branching, its deeply constricted, elliptical or oblanceolate segments, and its haptera representing entire, independent segments issuing at the constricted nodes.

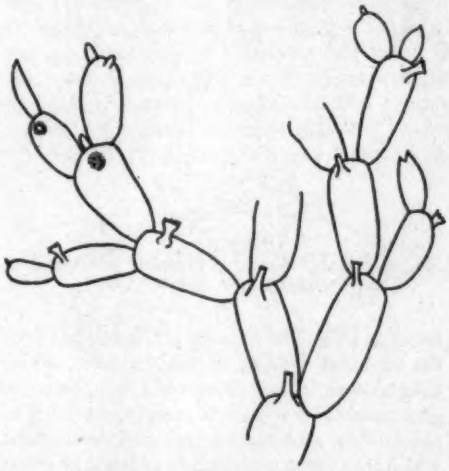

Fig. 2.—Habit sketch of *Catenella nipae* Zanard. About ×5.4.

2. Catenella nipae Zanard.

Figure 2

Catenella Nipae Zanard. Phyc. Ind. Pub. 143. 1872; De-Toni, Syll. Alg. 4: 321. 1897; Post, Notizen 68. 1936; Boergesen, *Cat. Nip.* Burma 266. 1938.

Catenella Opuntia Harv. Phyc. Austr. 5: pl. 296. 1863 [non *C. Opuntia* Good. & Woodw.) Grev.].

Catenella Opuntia var. *elatior* J. Ag. Sp. Alg. 3 (1): 588. 1876.

Plants of *C. nipae* are larger and stouter than those of the other known species of *Catenella*. The frond is creeping below and subflabellately caespitose, about 3 cm high. It is distinctly, deeply constricted and regularly, repeatedly

dichotomously to trichotomously branched. The segments are strongly compressed, elliptically oblong, sometimes obovate, reaching a breadth of 2 mm and about two to three

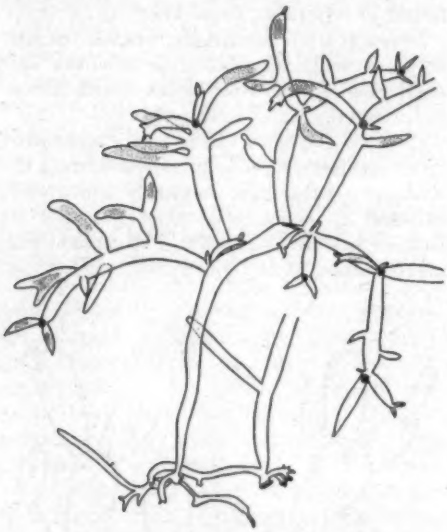

Fig. 3.—Habit sketch of *Catenella subumbellata* Tseng, sp. nov. About ×3.4.

times as long. The haptera are developed from the terminal ends of all the segments, which thus become limited. However, the subterminal growth of these segments usually continues to some extent after the formation of the haptera, which then become pushed to a lateral position, thus appearing subterminally situated (cf. Fig. 2). The branches of the next order originate close behind the haptera, which are actually the distal ends of the segments of the preceding order. These haptera always bend down ventrally, thus attaching the frond to the substratum. The few specimens collected are all sterile.

HABITAT: Forming decumbent patches on muddy rocks in sheltered salt marsh, in the littoral region, Shatin, Kowloon, in May 1940 (*Tseng 2788*).

DISTRIBUTION: Sarawak, Borneo (type locality); widely distributed in the area from Aru Islands, New Guinea and East Australia in the South Pacific, westward to Calcutta, India.

The present species is easily recognized by its regular, predominantly dichotomous branching, its large, stout, oblong, deeply constricted segments, and its terminal or seemingly subterminal haptera developed from all the segments.

3. **Catenella subumbellata** sp. nov.

Figures 3–5

Frons fusco-purpurea, surculis procumbentibus reptans, pulvinato-caespitosa, plerumque inferne unilateraliter vel subpinnata, superne subumbellatim ramosa; ramis ramulisque lineari-filiformibus, solum ad basin constrictis; fulcris flagelliformibus ad mediam partem subumbellarum formantibus, apud terminem ramorum praecedentium; tetrasporangiis ad apices solum articulorum aggregatis, inter fila moniliformia corticis positis, transverse divisis. Cystocarpia et spermatangia ignota.

Specimen typicum, *Tseng 2840* (in Herb. C. K. Tseng), ad rupes argillosas littoreas, in aqua tranquilla prope Taipo, Kowloon, 19 VI, 1940.

The new species has a dark purple frond, creeping with a slender, linear, procumbent, stolonlike part from which issue downward well-developed, primary, discoid holdfasts, attaching firmly to the substratum. The upper part is rather profusely branched, the branching usually subpinnate or rarely unilateral near the base and predominately repeatedly subumbellate upward (cf. Figs. 3 and 4). The segments are subcylindrical to slightly compressed, linear to elliptical in shape, reaching a breadth of 1 mm but generally much slenderer, usually only 500–800μ broad and generally three to six times as long, although in the lower subpinnately branched portions the segments may be more than ten times longer than broad. The terminal segments taper upward to a fine point, sometimes even aculeate. Constrictions as a rule are found only at the bases of the branches; in other words, there is usually only one segment to a branch.

Virtually all the segments are definite in growth and always terminate in the formation of a hapteron, soon after the formation of which two to four, sometimes more, new segment-initials are differentiated somewhere below, but always very close to it (cf. Fig. 4). At first this newly formed attachment organ occupies the central part, surrounded by the much younger

new segments, thus forming a more or less cymose "umbel." In the early stage of the development the hapteron, with its stalk now cut off from the mother segments, is still the most conspicuous in the pseudoumbel. Soon, however, because of its much slower growth, it becomes more and more obscured by the fast-growing young segments surrounding it (cf. Fig. 4). It also begins to bend more strongly toward the ventral side while the surrounding segments grow upward. When mature this hapteron, originally the apex of the preceding segment, becomes a comparatively obscure and insignificant discoid structure generally deflected ventrally, in the middle of the pseudoumbel, the segments of which have now branched repeatedly in a similar way, always with a similar attachment organ forming the center of each "umbel."

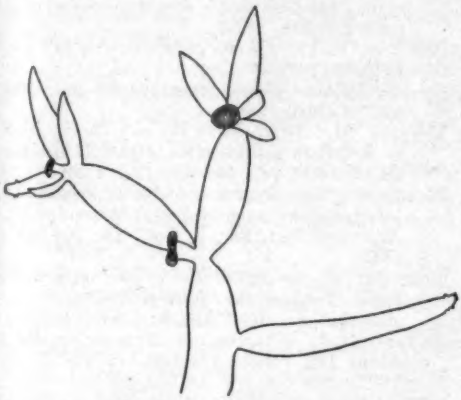

Fig. 4.—Upper portion of *Catenella subumbellata* Tseng, sp. nov., showing young and mature haptera. About ×8.

Internally, the structure of *C. subumbellata* is typical of members of this genus, that is, having a very lacunose medulla with interlacing, longitudinal filaments and a compact cortex of dichotomous, moniliform filaments. Specimens collected are all tetrasporic. Tetrasporangia are aggregated in the terminal segments. They are oblong and transversely, zonately divided, about 45–55μ broad and 60–70μ long, found between the moniliform filaments of the cortex (cf. Fig. 5).

HABITAT: Forming procumbent patches on muddy rocks in sheltered salt marsh in the littoral regions, Kowloon: Shatin, in May 1940 (*Tseng 2787*), and near the market, Taipo, in June 1940 (*Tseng 2840*, TYPE).

The present new species is most closely related to *C. nipae* in the similarity of hapteron formation. In both cases the haptera are the distal ends of the segments, not the whole segment as in the case of *C. impudica*. It is, however, distinctly different from *C. nipae* in the much slenderer, less stout, longer and linear-elliptical segments, in the predominantly subumbellate branching, sometimes subpinnate or unilateral near the base, and in the strictly terminal position of the haptera, which form the umbos of the pseudoumbels. In the umbellate branching it also resembles *C. impudica*, which differs, however, in having the independent segment type of hapteron; the latter is also much more robust and has more swollen and deeply constricted segments. The present species also reminds one somewhat of *C. repens* (*C. opuntia*). The latter, however, has a much more robust thallus, with strongly and regularly constricted branches, with much more compressed and laterally swollen segments, and with irregularly placed haptera, belonging to the emergent type and representing outgrowths rather than modified branches as in the cases of *C. nipae*, *C. impudica*, and the present species.

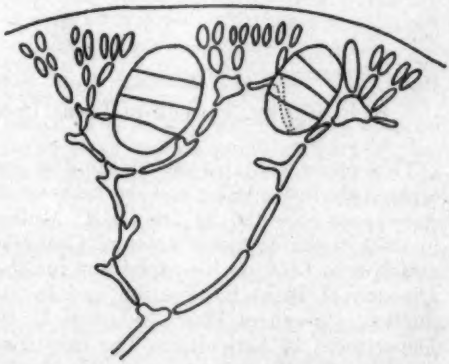

Fig. 5.—Transverse section of a segment of *Catenella subumbellata* Tseng, sp. nov., showing structure of frond and tetrasporangia. About ×247.

SUMMARY

From a single region three species of *Catenella* are found, including one new species, which are all recorded here for the first time from Hong Kong as well as from China as a whole. They are *C. impudica* (Mont.) J. Ag., *C. nipae* Zanard., and *C. subumbellata* Tseng, sp. nov., all fully described herein. They all represent plants of the salt-marsh flora of the Hong Kong region, the first one growing on trunks of mangroves and the last two on muddy rocks, all found in the littoral region and in very sheltered places.

The writer wishes to express his thanks to Prof. William Randolph Taylor, of the University of Michigan, for his advice during this study.

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BOTANY.—*New Asteraceae from northern Mexico collected by C. H. Muller.*[1]

S. F. BLAKE, Bureau of Plant Industry.

This paper contains descriptions of six apparently new species and one variety of Asteraceae collected by Dr. C. H. Muller in 1939 in the Mexican states of Coahuila and Nuevo Leon on his expedition for the Division of Plant Exploration and Introduction, Bureau of Plant Industry, U. S. Department of Agriculture. The only species here described of any particular phytogeographic significance is *Brickellia urolepis.* This is strikingly similar to *Brickellia hastata* Benth. of southern Baja California, and no very closely related species is known from the intervening region.

With the exception of the *Brickellia,* which was collected in Coahuila, all these plants come from the Sierra de la Cebolla, a part of the Sierra Madre about 50 miles south of Monterrey in Nuevo Leon. Dr. Muller informs me that a considerable number of new species in other groups were collected in the same range, which reaches an altitude of at least 2,900 m (9,500 feet) and is perhaps fourth in height among the mountains of Nuevo Leon. The name Sierra de la Cebolla does not occur on the officially published topographic map of Mexico ("Carta de la República Mexicana à la 100,000a"), but it is the range passing southwest of La Trinidad shown on sheet 11-III-(F) [published in 1904], and its location is approximately longitude 100°15 W., latitude 25° N.

Brickellia urolepis Blake, sp. nov.

Herba perennis infra inflorescentiam saepius simplex 6–11 dm alta, caulibus minute crispopuberulis foliosis; folia infimis exceptis alterna tenuiter petiolata linearia v. linear-lanceolata acuminata basi late hastata et saepe leviter cordata supra glabrescentia subtus crispe puberula vel hispidula et dense glanduloso-

[1] Received March 3, 1942.

adspersa; capitula mediocria 23–26-flora ca. 12 mm alta ca. 7–18 per caulem prope apicem caulis in ramis axillaribus 2–4-cephalis divergentibus 4–7 cm longis paucibracteatis v. subnudis paniculata, pedicellis tenuissimis crispopuberulis non glandulosis saepius 8–15 mm longis; involucri campanulati valde gradati 6–7-seriati appressi 10–12 mm alti phyllaria extima anguste subulata attenuata ca. 2 mm longa 0.5 mm lata puberula subherbacea ca. 1-costata apice interdum laxa, sequentia ovata 1–1.3 mm lata viridescentia v. purpurascentia albide 4–6-costata obtusa deinde abrupte subcirrhate herbaceo-appendiculata (appendice 0.5–0.8 mm longa) breviter ciliata prope apicem sparse puberula et sessili-glandulosa, sequentia lineari-oblonga obtusa v. acutiuscula brevi-ciliata ceterum glabra, intima linearia obtusa v. acuta laxe brevi-ciliata margine scariosa; achenia submatura 10-costata dense erecto-hispidula 4 mm longa; pappi albi 6 mm longi setae ca. 28 hispidulae.

Stems solitary or few, slender, from a short thick rhizome, the slender elongate roots sometimes tuberous-thickened at apex; lowest leaves (so far as seen) hastate-ovate, obtuse, ca. 5.5 cm long, 2–2.5 cm wide above the lobes; leaves thin, 3- or 5-plinerved, entire-margined (except for the basal pair of lobes), above green, minutely crisp-puberulous, glabrescent, beneath slightly paler green, the blade (middle leaves) 4.5–10.5 cm long, 2.3–6.5 cm wide at base (including the lobes), 7–10 mm wide above the lobes, the very slender petiole 7–20 mm long; heads at first nodding; disk (moistened) 12 mm high, 8 mm thick; involucre about equaling the corollas; corollas ochroleucous, subcylindric, 6.4 mm long, glabrous except for the apically sessile-glandular, semicircular, obtuse, apiculate teeth; undivided part of style 2.3 mm long, at base turbinate-thickened and densely tomentose, the branches linear-clavellate, 4.7 mm long.

MEXICO: Common in moist oak-maple woods, Cañon del Pajarito, Sierra de la Madera, Municipio de Cuatro Ciénegas, Coahuila, 6 Sept., 1939, *C. H. Muller* 3185 (type no. 145130, Nat. Arb. Herb.).

The only close ally of this species is the geographically remote *Brickellia hastata* Benth., of southern Baja California (Magdalena Bay and Santa Margarita Island). That is a shrubby plant; the leaves are mostly opposite, and well-developed ones bear 1 or 2 or sometimes several broad blunt teeth or short lobes above the basal pair; the 12–17-flowered heads are crowded at apex of stem and branches into close cymose panicles; and the conspicuous cirrhate phyllary tip of *B. urolepis* is absent or barely indicated.

Grindelia obovatifolia Blake, sp. nov.

Herba perennis erecta 3–5 dm alta; caules 1–2 simplices ubique villosi non glandulosi foliosi 1–2-capitati; folia basalia ovalia v. elliptica obtusa crenato-serrata utrinque villosa, lamina 4–5 cm longa 2–2.7 cm lata, petiolo vix marginato laminam subaequante saepe prope apicem lobos parvos foliaceos 1–2-jugos gerente; folia caulina 14–17, inferiora et media obovata obtusa sessilia amplectentia crenato-serrata dentibus obtusis supra ubique sed non dense hirsutula subtus in costa laxe villosa in superficie sparsius hirsutula et substipitato-glandulosa 3.5–6 cm longa 1.5–2.8 cm lata, superiora sensim minora oblonga v. elliptico-oblongo acutiuscula sessilia amplectentia; pedunculus 2–4 cm longus nudus: capitula (sicco) 2.8–4.2 cm lata non foliaceobracteata; involucri 7–9.5 mm alti gradati ca. 5–6-seriati parum resinosi phyllaria exteriora et media lanceolata v. extima subulata glabra (extimis dorso paullum villosulis exceptis) 0.8–1.5 mm lata, appendice herbacea anguste triangulari v. lanceolato-subulata 1.5–2.5 mm longa plana acuta patente non revoluta quam basi chartacea breviore donata, intima lineari-oblonga breviter acuminata non patentia non herbaceo-appendiculata; radii ca. 17–20, lamina 13–14 mm longa 4 mm lata; achenia submatura oblongo-obovata 3–3.5 mm longa apice truncato-rotundata edentata non rugosa; pappi aristae ut videtur 2–3 caducae subcapillares laevissimae subrectae 4.2–4.7 mm longae quam corolla paullo breviores.

Rhizome up to 10 cm long, 5 mm thick; basal leaves subcordate to acute at base, slightly stipitate-glandular beneath; stem leaves mostly somewhat longer than the internodes, thin-chartaceous, not resinous, closely crenate-serrate throughout, the teeth usually bearing a thick apical gland; disk depressed-hemispherical, 7–10 mm high, 1.3–1.7 cm thick (as pressed); rays golden-yellow, linear-elliptic,

2–3-denticulate; disk flowers numerous, their corollas golden-yellow, glabrous, 5–5.6 mm long (tube 2.2–2.5 mm, teeth 1 mm); style appendages triangular-ovate, acute, slightly shorter than the stigmatic lines.

MEXICO: Abundant throughout pine–oak and oak–Douglas fir forest, Transition Zone, east slope of Sierra de la Cebolla, Municipio de Montemorelos, Nuevo Leon, 21 Aug., 1939, *C. H. Muller* 2932 (type no. 145127, Nat. Arb. Herb.).

This plant is distinctive in appearance because of its decidedly obovate stem leaves. It is probably nearest *Grindelia robinsonii* Steyermark, of San Luis Potosi, a smaller plant with much shorter rays, smaller achenes, fewer stem leaves (only the lowest of which are obovate) and shorter and broader, mostly erect phyllary tips.

Erigeron basilobatus Blake, sp. nov.

Perennis rhizomatosus simplex 3.5–5 dm altus; caulis 1(–2)-capitatus patenti- vel reflexo-pilosus supra longe nudus; folia basalia subrosulata majuscula ovata obtusa grosse crenata vel sinuata basi abrupte in petiolum subaequalem anguste marginatum contracta saepe basi pinnatifida lobis 1–2-jugis oblongis obtusis 8–10 mm longis, utrinque non dense pilosa pilis patentibus basi plusminusve incrassatis, lamina 4–10.5 cm longa 2.8–4.5 cm lata; folia caulina 4–6, inferiora saepius oblonga v. ovata obtusa sessilia amplectentia grosse pauciserrata, superiora sensim minora oblonga integra, suprema multo minora lanceolata v. subulata bracteiformia; pedunculus nudus 6–19 cm longus; capitulum majusculum 3.5–4 cm latum; involucri 6–8 mm alti ca. 3-seriati paullum gradati phyllaria appressa lineari-lanceolata longe acuminata parce patenti-pilosa, interiora ca. 3-vittata anguste scarioso-marginata; radii numerosi albi ca. 3-seriati 12 mm longi 1.2 mm lati; achenia hirsutula 2-nervia; pappus simplex persistens.

Rhizomes creeping, slender, 8 cm long and more, bearing 1–3 terminal flowering stems or sometimes a sterile rosette; stem naked in its upper half or third, rarely bearing a single erect 1-headed branch from below the middle, the hairs in its lower part spreading or reflexed, many-celled, white, about 1 mm long, those in its upper part reflexed; petioles of basal leaves 3.5–5.5 cm long; crenations or lobes of the leaves blunt, callous-apiculate like the apex of leaf; lower stem leaves 5.5–8.5 cm long, 1.5–2.5 cm wide, the upper 2–4.5 cm long, 0.8–1.8 cm wide; disk (as pressed) 1.3–1.5 cm wide, about 8 mm high; rays numerous (100 or more), sparsely puberulous at apex of tube, about 14 mm long (tube 2 mm, lamina linear, 12 mm long, 1.2 mm wide, 2-3-denticulate, 3–4-nerved); disk flowers very numerous, their corollas yellow, glabrous except for the sparsely puberulous and apically slightly crested teeth, 4 mm long (tube 1.2 mm, throat 2.2 mm, teeth 0.6 mm long); disk achenes (immature) oblong, compressed, 2-nerved, 1 mm long, sparsely hirsutulous, their pappus simple, of about 28–30 slender subequal hispidulous bristles 2.5–3 mm long; ray achenes and pappus similar; style branches with very short deltoid obtusish hispidulous appendages.

MEXICO: Common in pine-oak forest, east slope of Sierra de la Cebolla, Municipio de Montemorelos, Nuevo Leon, 21 Aug., 1939, *C. H. Muller* 2934 (type no. 145128, Nat. Arb. Herb.).

A comparatively coarse plant, rather distinctive in appearance because of the large, usually basally pinnatifid basal leaves and greatly reduced, mostly clasping and entire stem leaves.

Erigeron metrius Blake, sp. nov.

Perennis saepius pauciramosus adscendens v. decumbens 3–6 dm altus ubique dense canescenti- vel cinereo-pilosus foliosus; folia internodiis subaequalia sessilia integra inferiora anguste obovata obtusiuscula 2–2.5 cm longa 4–7 mm lata superiora anguste elliptica v. lineari-oblonga sensim minora; capitula in apicibus caulis et ramorum solitaria longe pedunculata 2–2.3 cm lata; involucri ca. 3-seriati paullum gradati 5 mm alti phyllaria linearilanceolata acuminata dense pilosa; radii numerosi albi roseo-tincti ca. 7 mm longi; achenia 2-nervia hirsutula; pappus e corona brevi lacerato-ciliata et aristis ca. 10 fragilibus sistens.

Stem 1–2 mm thick at base, usually with few ascending branches, sometimes simple and 1-headed, densely pilose with slenderly conical-based few-celled white hairs 1–2 mm long, the hairs varying from wide-spreading on lower

part of stem to subappressed on the peduncles; internodes mostly 5–15 mm long; leaves alternate, densely pilose on both sides with spreading or subascending hairs with small tuberculate bases, the lower obtuse to acutish, weakly 3-nerved, the upper 1–1.5 cm long, 1.5–3 mm wide; peduncles 6–14 cm long, canescent-pilose with erectish or subappressed hairs; rays 100 or more, 3-seriate, white, rosy on the back, sparsely pubescent on tube, 8 mm long (tube 1.5 mm, lamina linear, 2–3-denticulate, 4-nerved, 6.5 mm long, 0.8–1 mm wide); disk corollas very numerous, yellow, sparsely puberulous toward base of tube, hispidulous-crested on teeth, 2.7 mm long (tube 0.7 mm, throat 1.5 mm, teeth 0.5 mm long); disk achenes (very immature) oblong, erect-hirsutulous, 2-nerved, their pappus of a laceriate-ciliate basally connate crown of squamellae about 0.4 mm long and about 10–13 fragile hispidulous bristles 2.5 mm long, the whole in a single series; ray achenes and pappus similar; appendages of the style branches (disk flowers) so short as to make the tips appear subtruncate; anther tips narrowly triangular.

MEXICO: Scattered in chaparral, upper west slope of Sierra de la Cebolla, above 2750 m altitude, Municipio de Rayones, Nuevo Leon, 21 Aug., 1939, *C. H. Muller* 2914 (type no. 145126, Nat. Arb. Herb.).

A member of the group of Erigeron centering about the imperfectly known *Erigeron pubescens* H.B.K., but apparently distinct from any described species.

Sabazia mullerae Blake, sp. nov.

Perennis gracilis decumbens nodis infimis radicantibus 2.5–3 dm longa; caulis simplex v. breviter ramosus subsparse pilosus, pilis inferioribus patentibus superioribus erectis v. subappressis; folia (inferioribus delapsis exclusis) ca. 4–6-juga lanceolato-ovata acuta basi cuneata v. rotundato-cuneata pauciserrata brevissime petiolata subsparse pilosa; pedunculi solitarii terminales 1-capitati 9–16.5 cm longi; capitulum 1.5–1.8 cm latum; involucri 5–6 mm alti 3-seriati gradati phyllaria ovata acutiuscula v. obtusa basi albida subchartacea supra membranaceo-herbacea ciliata ceterum glabra 3–5-vittata; radii 10–13 albi dorso roseo-tincti alte 3-dentati; achenia radii glabra epapposa, disci hispidula pappifera, pappo sub-3-seriato gradato ca. 25-aristato persistente.

Stem about 1 mm thick, usually with few short erectish branches below, pubescent with mostly spreading hairs below, erect- or subappressed-pilose above; leaves opposite; internodes 1.8–4 cm long, mostly surpassing the leaves; petioles narrowly margined, 1–2 mm long; blades 1.8–2.8 cm long, 7–12 mm wide, rather sparsely pilose on both sides with more or less ascending subtuberculate-based white hairs, few-serrate (teeth 2–3 pairs, remote, callous-tipped, 0.5–1 mm high), triplinerved; peduncles rather sparsely pilose with erectish hairs; phyllaries 1.5 (outer) to 2.5 mm wide, the outer rather stiffly white-ciliate, the inner more loosely pilose-ciliate with many-celled purplish-based hairs, on back glabrous or the outer with a few hairs along the midrib; ray flowers fertile, the corolla densely pilose on tube, 8–9 mm long (tube 2 mm, limb cuneate-oblong, 7–8-nerved, 6–7 mm long, about 3.5 mm wide, the teeth ovate, obtuse, 1.5–2 mm long); disk flowers numerous, their corollas yellow, densely pilose on tube, hirsutulous outside and papillose within on teeth, 3.4 mm long (tube 1.2 mm, throat 1.6 mm, teeth 0.6 mm long); outer pales lance-ovate, usually abruptly contracted near middle and there often with a shoulder or short tooth on one or both sides, submembranous, 4–5 mm long, about 1.5 mm wide, 3–4-vittate, obscurely ciliolate, the inner narrowly lanceolate, 3.5 mm long, 0.5 mm wide, entire; ray achenes obcompressed, obovoid, glabrous, epappose, 2 mm long; disk achenes (not quite mature) obovoid, plumpish, erect-hirsutulous, 2.2 mm long, their pappus of about 25 graduated sub-3-seriate linear-lanceolate hispidulous-ciliolate awns, the outer about 1.5 mm, the inner 2.8 mm long.

MEXICO: Sparse in open chaparral, upper west slope of Sierra de la Cebolla, above 2750 m altitude, Municipio de Rayones, Nuevo Leon, 21 Aug., 1939, *C. H. Muller* 2902 (type no. 145123, Nat. Arb. Herb.).

This species, the northernmost true member of the genus, is nearest *Sabazia triangularis* var. *papposa* Blake, of Chiriqui, Panama, and *S. pinetorum* var. *dispar* Blake, of Guatemala, and is very similar to both of these in habit. In the former the pappus of the disk achenes consists of 5–6 obtuse squamellae 0.8 mm long.

In the latter the stem is ascending- or subappressed-pubescent, the upper leaves are decidedly narrower than the lower, and the pappus is definitely double, the outer series consisting of 10 acuminate or obtusish linear awns 1.2–1.7 mm long, the inner of 10 subaristate lanceolate awns 2.5 mm long. *Sabazia anomala* Greenm. and *S. leiachenia* Blake, the only other pappiferous species of the genus, are erect or erectish annuals with a pappus of 10 equal 1-seriate blunt squamellae.

The species is named for Mrs. Katherine Muller, who accompanied her husband on the expedition and assisted in the field work.

Tagetes mulleri Blake, sp. nov.

Perennis simplex v. erecte ramosa ca. 7 dm alta foliosa ubique glaberrima, venis paginae superioris foliorum et dentibus involucri minute puberulis exceptis; folia majuscula pinnatisecta, segmentis majoribus 3–4-jugis cum terminali lanceolato-ellipticis v. lanceolatis acuminatis crebre et acutissime serratis disperse punctatis lateralibus 2.5–4.5 cm longis 8–17 mm latis, jugis 2 infimis multo minoribus laceratis additis, rachi angustissime marginata; capitula apice caulis terna et in apice rami solitaria majuscula ca. 4 cm lata, pedunculis sparse bracteatis 5.5–8.5 cm longis; involucri campanulati 11 mm alti ca. 8-dentati, dentibus deltoideis acutiusculis apice 1-glandulosis et dense sordide puberulis, tubo lineis duplicibus glandularum praedito; radii 8 magni flavi ca. 2 cm longi; corollae disci nigro-virides; achenia supra sparse hispidula 7 mm longa; pappi aristae 4–6 lineari-lanceolatae acuminatae 4–5.5 mm longae cum squamellis 5–7 similibus multo brevioribus alternantes, omnes liberae.

Stem solitary from a slender running rhizome or this sometimes apparently deeper and vertical, 2–4 mm thick below, subterete, multistriate, somewhat angled above, pithy, simple below the inflorescence or with few erect branches; leaves opposite; internodes mostly 3–6 cm long, much shorter than the leaves; leaves including petiole 8–12 cm long, 4–9 cm wide, the proper petiole (below the lowest pair of leaflets) only 3–5 mm long, the 2 lower pairs of leaflets deeply laciniate, 4–9 mm long, the segments cirrhus-tipped, the principal leaflets 3–4 pairs, sharply and closely serrate with mostly simple triangular 1-glandular cuspidate teeth 1.5–2 mm long, acute at base, rather sparsely punctate with small round glands, above dark green, minutely and sparsely hispidulous along the veins, beneath lighter brighter green, glabrous, the terminal leaflet up to 5.5 cm long, 1.8 cm wide; peduncles slender, striate, not distinctly thickened below the head; each phyllary bearing a terminal linear-oblong gland and (on the tube) 2 rows of 4–5 glands each, the upper roundish, the lower oblong-linear, the teeth densely sordid-puberulous toward apex; rays "deep yellow," 2.5 cm long, glabrous (tube 5 mm, lamina obovate-oblong, 3-denticulate, 8-10-nerved, 2 cm long, 7 mm wide); disk corollas blackish-green, obscurely puberulous at base of throat, 7.5 mm long (tube 3 mm, throat slender, 2 mm, teeth oblong, acute, 2.5 mm long); achenes of ray and disk similar, linear, slightly hispidulous above on the angles, 6.5–7 mm long; pappus essentially similar in ray and disk, of 4–6 narrowly linear-lanceolate, acuminate, hispidulous-ciliolate awns (3) 4–5.5 mm long, and about 5–7 acuminate or sometimes obtuse and lacerate-tipped, narrowly linear to linear-lanceolate squamellae 1–2.5 mm long, all free; style branches with deltoid, hispidulous, abruptly and slenderly cuspidate-tipped appendages.

MEXICO: Very abundant on moist slopes, in pine forest, trail from La Trinidad up the Sierra de la Cebolla, Municipio de Montemorelos, Nuevo Leon, 20 Aug., 1939, *C. H. Muller* 2869 (type no. 145122, Nat. Arb. Herb.).

Allied to *Tagetes lemmoni* Gray and *T. palmeri* Gray but with relatively broader leaflets, distinctive pappus, and many minor differential characters.

Psacalium peltatum var. **adenophorum** Blake, var. nov.

Inflorescentia dense glanduloso-puberula pilis aliis brevibus pluriloculatis aliis longioribus crasse conicis vel basi inflatis, omnibus apice glanduliferis; involucrum similiter sed minus dense glandulosum.

MEXICO: Common in chaparral on both sides of the mountain, upper west slope of Sierra de la Cebolla, above 2750 m altitude, Municipio de Rayones, Nuevo Leon, 21 Aug. 1939, *C. H. Muller* 2911 (type no. 145124–5, Nat. Arb. Herb.).

In typical *Psacalium peltatum* (H. B. K.) Cass., as represented in the U. S. National Herbarium by *Pringle* 3340 and *C. & E. Seler* 1259 from the vicinity of Patzcuaro, Michoacan, the type locality, the inflorescence and involucre are densely villous with many-celled, loosely spreading, eglandular white hairs. In Pringle 9871, from Cuernavaca, Morelos, which Rydberg[2] has referred to *P. peltatum*, the inflorescence is pilosulous or villosulous with shorter hairs containing much purplish coloring matter but without evident terminal glands. In the very closely allied and probably not specifically distinct *P. argutum* Rydb., from Durango and San Luis Potosi, the pubescence is much as in *Pringle* 9871, but perhaps shorter and stiffer. Although the difference in pubescence between var. *adenophorum* and typical *P. peltatum* would ordinarily indicate specific distinctness in this group, it is apparently not reinforced by any other distinctive characters, and the form collected by Dr. Muller seems, on the whole, best regarded as of only varietal rank.

[2] Bull. Torrey Bot. Club 51: 373. 1924.

ZOOLOGY.—*Are "frontoparietal" bones in frogs actually frontals?*[1]

THEODORE H. EATON, JR., Cornell University. (Communicated by C. LEWIS GAZIN.)

Recently the writer (1939) showed that in *Rana clamitans*, *Hyla regilla*, *Bufo californicus*, and *Scaphiopus hammondii* the so-called "frontoparietal" bones each develop from a single center of ossification instead of from two, as stated by W. K. Parker (1871) for *Rana temporaria*. Parker's opinion, which has been repeated by many writers, was that the anterior center represented the frontal, the posterior the parietal; hence the compound name for the adult bones. He also (1876) speaks of the "frontoparietals" as being "double bones" in *Bufo vulgaris*.

Since 1939 I have found that in *Pseudis paradoxa* (Figs. 1–4), *Rana esculenta* (Figs. 5–7), *R. temporaria* (Parker's species; Fig. 8), and *Dendrobates auratus* (Fig. 9) these bones develop from single centers, just as in the four types described previously. Cleared larvae of *Rana catesbeiana* and two late larvae of *R. aurora draytonii* that I examined also agree with these.

The apparent reason for Parker's statements and figures is this: Under a dissecting microscope the wet, illuminated surface of each "frontoparietal" at an early stage reflects an anterior and a posterior ring of light where it bulges over the forebrain and midbrain, respectively. These rings correspond with the edges of Parker's "frontals" and "parietals," but they indicate only convexities, not separation. Sometimes there are circles of melanophores (Fig. 8), giving the same illusion.

The fact that no exception is found among these several genera, and even in Parker's species, to the rule of development from *single* sliverlike centers of ossification suggests that this method may be universal in Salientia and that no evidence exists to warrant the term "frontoparietal."

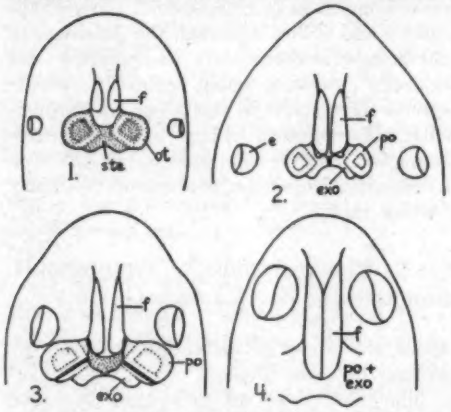
Another statement by Parker (1877) is the following, called to my attention by Prof. E. L. Rice, of Ohio Wesleyan University: "In the small frog, *Pseudis paradoxa* . . . the parieto-frontals arise as one bone on either side, and are subsequently segmented into parietal and frontal." The series I examined, however, verifies only the first half of this sentence. There was no trace of subsequent segmentation (Figs. 1–4).

In *Pipa parva* the right and left "frontoparietals" fuse in the median line, making a single broad plate over the brain, even in larvae in which the legs are not yet well developed (for example, head–body length 15 mm, tail 25, foreleg 3, hindleg 9). In my series, unfortunately, no younger stages were available.

The general scheme of development of these bones in Salientia, then, is as follows: They first appear, one on each side, above the lateral wall of the cranium, fitting the depression between cerebral hemispheres and optic lobes; this is in half-grown or slightly older larvae. Extending forward and

[1] Received November 29, 1941.

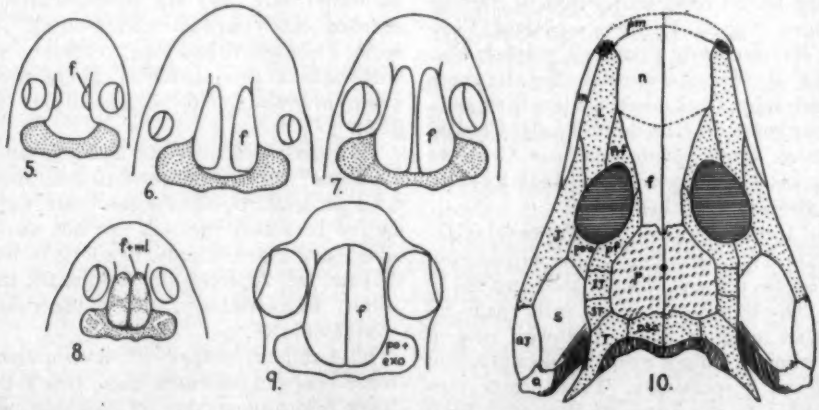
back they reach the ethmoid cartilage and synotic tectum, partly overlapping each. This stage, in which they are slender, widely separated strips of bone, is passed



Figs. 1–4.—*Pseudis paradoxa:* 1, Larva (148 mm, head–body 54 mm, hindlegs minute), dorsal view of cranium, stippled parts cartilage; 2, neotenic larva (188 mm, head–body 64 mm, legs large); 3, transforming (140 mm, head–body 44 mm, hindlegs large, one foreleg out); 4, adult head-body 53 mm).

in the late larvae of most species, but in *Hyla* and *Pseudacris* it is retained in the adult. With most genera, as *Rana*, *Bufo*, *Pseudis*, *Dendrobates*, and *Scaphiopus*, the "frontoparietals" spread to meet in the median line at or before transformation, but a permanent suture remains. Only in *Pipa*, of the types I have seen, does this suture disappear.

The next question concerns the homology of these bones. As the Salientia are in all probability derived from early labyrinthodonts, we may to advantage compare the frog skull with that of the Carboniferous *Paleogyrinus decorus* (Fig. 10). The Salientia lack most of the dermal roofing bones, those that are stippled in the figure. This loss affects two regions, the orbital and temporal, and may be correlated with (*a*) shortening of snout with relative enlargement of eyes, and (*b*) dorsomedial spread of the area of origin of the temporal muscles, which in a labyrinthodont filled a narrow space beneath the roofing bones, lateral to the wall of the cranium. In the posterior part of the skull a frog retains no dermal bones except the quadratojugal and squamosal, both of which lie entirely lateral to the jaw muscle origin on the prootic. Postorbital, postfrontal, intertemporal, supratemporal, tabular, and dermosupraoccipital are missing. Since these extend around three sides of the parietals in *Paleogyrinus*, it is highly probable that the latter also atrophied in response to the same influence, leaving the frontals to extend somewhat posteriorly as



Figs. 1–7.—*Rana esculenta:* 5, Larva (32 mm, head–body 16 mm, short legs); 6, larva (63 mm, headbody 25 mm, short legs); 7, transforming (21 mm, head–body 15 mm, four legs, tail stump.)
Fig. 8.—*Rana temporaria:* Late larva (57 mm, head–body 22 mm, hindlegs 21 mm).
Fig. 9.—*Dendrobates auratus:* Late metamorphosis (head-body 14 mm).
Fig. 10.—*Paleogyrinus decorus* (adapted from Watson, 1926, fig. 13):
Stippled bones are those absent in frog skull.

the snout shortened and eyes enlarged. For these reasons, in the absence of any developmental evidence in modern frogs, it appears likely that the "frontoparietals" are frontals only.

For the use of specimens in this study I wish to thank Dr. Arthur Loveridge, Museum of Comparative Zoology (*Pseudis paradoxa*, *Rana temporaria*, and *R. esculenta*); Dr. C. M. Bogert, American Museum of Natural History (*Pseudis paradoxa*); Mr. Edgardo Mondolfi, Caracas, Venezuela, and Dr. Doris M. Cochran, U. S. National Museum (*Pipa parva*).

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ABBREVIATIONS FOR FIGURES

dso = dermosupraoccipital
e = eye
exo = exoccipital
f = frontal
f+ml = frontal with rings of melanophores
it = intertemporal
j = jugal
l = lacrimal
m = maxillary
n = nasal
ot = otic capsule
p = parietal
pf = postfrontal
pm = premaxillary
po = prootic
poo = postorbital
prf = prefrontal
q = quadrate
qj = quadratojugal
s = squamosal
st = supratemporal
ste = synotic tectum
t = tabular

ICHTHYOLOGY.—*Notes on some fishes from the Gulf of California, with the description of a new genus and species of blennioid fish.*[1] LEONARD P. SCHULTZ, U. S. National Museum.

Among some fishes sent to the United States National Museum from the Gulf of California, a blennioid fish was found to be undescribed and other species are worthy of report. The author wishes to thank E. F. Ricketts for sending these specimens in for study.

Hypsoblenniops, new genus

After studyin the fishes related to *Hypsoblennius* and Herre's description of his *Spinoblennius* (Herre, Field Mus. Nat. Hist. Publ. Zool. **18** (12): 435. 1935, type *S. spiniger;* Herre, *ibid.* **21**: 399, fig. 39. 1936), along with a paratype of *S. spiniger* kindly sent from the Field Museum to the United States National Museum, I have considered it best to propose a new genus for this little blenny from the Gulf of California.

Genotype: *Hypsoblenniops rickettsi*, new species.

Named *Hypsoblenniops* in reference to its relationship with *Hypsoblennius*.

This new genus is close to *Hypsoblennius* Gill and *Spinoblennius* Herre but differs from the former in having the preopercle armed with three strong spines, one at the lower angle and a smaller one above and another below that spine, and from the latter in having three slender, pointed preopercular spines instead of a single flat one at the lower angle.

A simple tentacle about ½ to ⅓ diameter of eye occurs on its upper margin. All cirri are said to be lacking in *Spinoblennius spiniger* Herre, but an examination of one of his paratypes shows a small, simple ocular tentacle, its length about ⅔ the pupil. The anterior nostril near front of eye is tubular, with a very small cirrhus on its dorsal margin in the new species but rudimentary in *Spinoblennius*, though said in the original description to be lacking.

[1] Published with the permission of the Secretary of the Smithsonian Institution. Received December 26, 1941.

The lateral line is incomplete, of about 9 to 11 pores, ending over a verticle through the anus; the gill membranes are attached as far up as the lower edge of the base of the pectoral fin; teeth more or less rigid, set on jaw bones and not on the fleshy lips; no canine tooth at corner of mouth; about 16 teeth in each jaw.

Hypsoblenniops rickettsi, new species

Fig. 1

Holotype.—A specimen (U.S.N.M. no. 119731) 19.8 mm in standard length was taken by E. F. Ricketts in Concepcion Bay, Mexico, the night of March 28, 1940, by a light while at anchorage, along with eight paratypes bearing same data, U.S.N.M. no. 119732. In addition, one paratype was taken in San Carlos Bay, Mexico, at night by use of a light, April 4, 1940, by E. F. Ricketts, U.S.N.M. no. 119733.

Fig. 1.—*Hypsoblenniops rickettsi*, new species. Photograph of holotype, U.S.N.M. no. 119731. The preopercular spines have been outlined on the photograph to bring out their shape.

Description.—Based on holotype and 9 paratypes. The counts and measurements are given first for the holotype and then for certain of the paratypes, respectively. The standard lengths are 19.8; 20.2; and 18.3 mm. Total lengths 24.5, 23.1, and 22.1 mm. All the following measurements are expressed in hundredths of the standard length: Length of head 31.3, 28.7, 30.6; length of snout 8.6, 7.4, 8.7; diameter of eye 10.1, 9.9, 12.0; postorbital length of head 14.1, 14.9, 15.3; width of interorbital space 7.1, 7.4, 8.2; length from front of premaxillary to rear edge of maxillary 9.1, 9.4, 9.8; greatest depth (at rear of head) 20.2, 21.3, 23.0; least depth of body 7.1, 7.9, 8.7; distance from tip of snout to origin of dorsal fin 27.3, 26.7, 27.5; snout to origin of anal 52.0, 46.6, 49.2; length of longest ray of caudal fin 24.2, 21.8, 24.0; longest ray of pectoral 27.8, 25.2, 29.0; longest pelvic ray 20.2, 21.3, 20.7; longest dorsal spine (third) 11.1,—, 12.0; longest soft ray of anal 8.6,—,9.3.

The following counts were made respectively: Dorsal rays XII, 16; XII, 16; XII, 16; XII, 16; XII, 16; XII, 16; XII, 16; anal rays ii, 18; ii, 18; ii, 19; ii, 18; ii, 17; ii, 18; ii, 19; pectoral rays 12–12; 12–12; 12–12; 12–12; 12–12; pelvics usually I, 2, occasionally I, 3; pores in lateral line 9;—; 10; 9; 11; branchiostegals 5.

The lower rays of the pectoral fin are a little exserted and enlarged; the large eye is mostly in the anterior half of the head; the maxillary extends to below the front of the pupil: the head is blunt forward, with a rounded profile, and the mouth not quite so far forward as region in front of eyes; the body is compressed; top of head flat, with some more or less hardened skin in region of occiput.

The color pattern in alcohol of *Hypsoblennius rickettsi* consists of six bars or dorsal saddles, all situated under the dorsal fin and extending down to midsides, on some specimens ending there as an inverted V-shaped mark or in others the Λ-shaped marks extend to the anal fin in an irregular manner; these dorsal saddles divide into a U-shaped mark on the dorsal fin to form 12 bars on it; the lower six rays of the pectoral fin are blackish, the upper rays hyaline; at the base of each anal ray is a black pigment spot; the under side of the head is crossed with three dark bars, the first from below front of

eye through corner of mouth meeting its fellow on chin, although front of chin is pale; the second bar from below eye meets its fellow on under side of head; the third, less distinct than the others, ends at base of branchiostegals; tip of snout with two narrow dark color bars separated by a pale space, rear of head pigmented; base of rays of caudal fin pigmented, forming a dark wavy line.

In color pattern this new species resembles *Spinoblennius spiniger* Herre. *S. spiniger* has XII, 11 dorsal and II, 15 or 16 anal rays in contrast to XII, 16 and II, 17 to 19 in *Hypsoblenniops rickettsi*.

Named *rickettsi* in honor of E. F. Ricketts, of the Pacific Biological Laboratory, who was responsible for the collection of the specimens.

Genus **Chaenopsis** Gill

Chaenopsis Gill, Ann. Lyc. Nat. Hist. New York **8**: 141, pl. 3, fig. 3. 1863 (type, *C. ocellatus* Poey).
Lucioblennius Gilbert, Proc. U. S. Nat. Mus. **13**: 103. 1890 (type, *L. alepidotus* Gilbert).

After having examined the types of the species referred to the genera *Chaenopsis* and *Lucioblennius*, as well as other specimens in the United States National Museum, I am convinced that only a single species should be recognized in the American waters of the Pacific Ocean and only one in the American waters of the Atlantic Ocean. The types of *Lucioblennius alepidotus* and *L. lucius* are small specimens in poor condition and difficult to study. With the aid of a binocular microscope it is thought that the fin rays have been counted correctly, and my counts differ considerably from those in current descriptions. Data are given in the accompanying table.

The number of spines in the dorsal fin appears to be from XVIII to XX in both species, although it is difficult to determine the first soft ray. There are 13 rays in the pectoral fins and 12 or 13 rakers on the lower part of the first gill arch. Sometimes a few rudiments occur between the main rakers, these not included in the above counts. Probably the vomer always has a few very weak teeth. This character is more strongly developed in the Atlantic specimens than in the Pacific ones.

Chaenopsis alepidotus (Gilbert)

Lucioblennius alepidotus Gilbert, Proc. U. S. Nat. Mus. **13**: 103. 1890.
Lucioblennius lucius Osburn and Nichols, Bull. Amer. Mus. Nat. Hist. **25**: 179, fig. 15. 1916.

The following specimens in the U. S. National Museum have been examined:

U.S.N.M. no. 44373 (co-type of *L. alepidotus*), lat. 25°02′30″ N., long. 110°43′30″ W., March 17, 1889, *Albatross*.
U.S.N.M. no. 48264 (co-type of *L. alepidotus*), lat. 25°02′45″ N., long. 110°43′30″ W., March 17, 1889, *Albatross*.
U.S.N.M. no. 87550[2] (type of *L. lucius*), San Josef Island, 1911, *Albatross*.
U.S.N.M. no. 56396, Santa Catalina Island, Miss Frances Lauderback.
U.S.N.M. no. 102159, San Gabriel Bay, Espiritu,

[2] Catalogued in American Museum by error as no. 5207.

TABLE 1.—DORSAL AND ANAL FIN RAY COUNTS MADE ON THE TWO SPECIES OF CHAENOPSIS

Specimen	Standard length (in mm.)	Dorsal rays					Anal rays			
		52	53	54	55	56	36	37	38	39
C. ocellatus:										
U.S.N.M. no. 8007	110.5	—	1	—	—	—	—	1	—	—
U.S.N.M. no. 116807	46–88	1	3	2	—	—	2	2	2	—
Total		1	4	2	—	—	2	3	2	—
C. alepidotus:										
U.S.N.M. no. 44373	34.0	—	—	1	—	—	1	—	—	—
U.S.N.M. no. 48264	33.5	—	1	—	—	—	—	1	—	—
U.S.N.M. no. 87550	36.7	—	1	—	—	—	1	—	—	—
U.S.N.M. no. 56396	153.0	—	—	—	—	1	—	—	—	1
U.S.N.M. no. 101948	39.5	1	—	—	—	—	—	—	1	—
U.S.N.M. no. 102159	45.4	—	1	—	—	—	—	1	—	—
U.S.N.M.	120.0	—	—	—	1	—	—	1	—	—
Total		1	3	1	1	1	2	3	1	1

Santo Island, 1 to 4 fathoms, February 22, 1936, Hancock Expedition.
U.S.N.M. no. 101948, Playa Blanco, Costa Rica, February 8, 1935, W. L. Schmitt, U.S.N.M. no. 119721, Concepcion Bay, March 29, 1940, E. F. Ricketts, Pacific Biological Laboratory.

Jordan and Starks (Proc. U. S. Nat. Mus. 32: 74–76, fig. 7. 1907) give an excellent figure of this species. There are a few tiny teeth at the head of the vomer that show up in clay impressions not visible otherwise.

Chaenopsis ocellatus Poey

Chaenopsis ocellatus Poey, *in* Gill, Ann. Lyc. Nat. Hist. New York 8: 143. 1863.

The following specimens are in the U. S. National Museum and have been examined:

U.S.N.M. no. 8007 (type of *C. ocellatus*), Cuba, Prof. F. Poey.
U.S.N.M. no. 116807, Tortugas, Fla., W. H. Longley.

Longley and Hildebrand (Papers Tortugas Lab. Carnegie Inst. Washington 34: 275–276. 1941) give an excellent color description of this species.

Description of the Adult of Porichthys analis Hubbs and Schultz

The original description of *Porichthys analis* Hubbs and Schultz (Proc. U. S. Nat. Mus. 86: 485. 1939) was based on two small specimens 95.5 and 80 mm in standard length, the only known examples of this toadfish then known. It now gives me pleasure to describe an adult of this species, 255 mm in standard length and 280 mm from tip of snout to tip of tail.

The following measurements are expressed in hundredths of the standard length: Greatest depth 17.5; distance from tip of snout to origin of soft dorsal 35.5; and to origin of spinous dorsal 27.9; from tip of chin to anus 39.4; length of head 28.1; interorbital width 11.8; length of orbit 3.3; length of upper jaw 15.8; length of snout 7.6; distance from tip of lower jaw to tip of V of branchiostegal row of photophores 8.3; least distance between the nearly parallel ventral rows of photophores 3.9; distance from anus to anterior extension of ventral row of photophores 16.3; height of pectoral arch of pleural row of photophores 5.5; length of this arch 9.4.

Teeth on premaxillaries, vomer and dentary hooked backward, those on palatines mostly in a single row hooked inward; dorsal and anal fins free from the caudal; pectoral fin pointed medially; peritoneum black; lateral line organs essentially as described for the young of this species.

The color in alcohol is dark above, paler below with a tinge of brown, with 7 or 8 dorsolateral dark bars that are obscured forward more or less by the uniform dark color of the upper parts of the body, but more evident posteriorly; the dorsal fin has 7 obliquely directed darkish bars, but these are separated from those on the body at the base of the fin by the obliquely directed pale areas, except the first one at the origin of the soft dorsal fin; base of caudal fin blackish, then across the middle of this fin is a wide pale band; the distal half of the caudal fin is blackish; pelvics and pectorals dusky; basal half of anal fin pale, the distal margin with a wide blackish band; area under pectoral fin base (axil) pale; upper part of lower lip dark with white band below that extends to behind maxillary and joins a more extensive pale area.